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TECHNICAL MEMORANDUM 1072

REDEYE

TARGET DETECTION STUDY

March 1963

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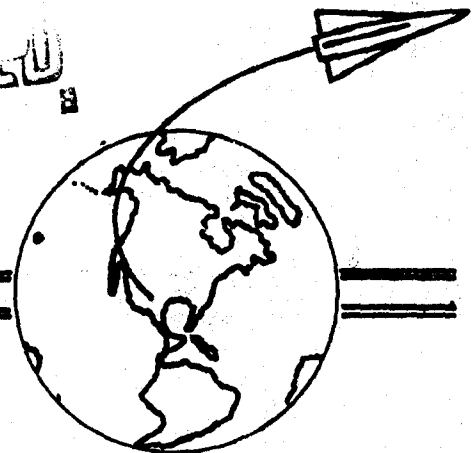
THE ARMY MISSILE TEST AND EVALUATION DIRECTORATE

WHITE SANDS MISSILE RANGE
NEW MEXICO

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REDEYE

TARGET DETECTION STUDY

By: Lt W. J. Zimmer
C. F. McGinnis

March 1963

Approved:

A. K. Tischler

for P. L. HORNE JR.
Lt Col, OrdC
Chief, Systems Test Division

Released:

E. S. Southworth

E. F. SOUTHWORTH
Redeye Project Manager

Systems Test Division
The Army Missile Test and Evaluation Directorate
WHITE SANDS MISSILE RANGE
NEW MEXICO

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U. S. Army Aviation Section, Fort Bliss, Texas.

ABSTRACT

The Redeye target detection study was conducted by White Sands Missile Range at Dona Ana Range, Ft Bliss, Texas, during the period 17 through 27 October 1961. Tests were conducted to determine the range at which "average" soldiers, without optical aids, could visually detect target aircraft.

Analysis of the data provided detection range information as a function of target type, altitude, direction, speed, and degree of prior information provided the subjects. The following general results were obtained:

Overall number of detections	2,232
Overall mean detection range	5,130 yards
Overall median detection range	4,550 yards
Range limits containing 90 percent of detections	1,200-11,200 yards

The mean detection range for each of the four aircraft is as follows:

Propeller (L-23)	7,400 yards
Helicopter (H-23)	5,560 yards
Jet (F-100)	4,430 yards
Jet (T-33)	3,290 yards

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TABLES

FIGURES

INTRODUCTION

This test was conducted as part of the Redeye Engineering Evaluation Program, in compliance with the requirements of Redeye Operational Test Plan 6A, dated August 1961.

The Redeye operator, as an integral part of the Redeye weapon system, is responsible for the visual detection of target aircraft. This report presents a definition of the detection boundaries for certain classes of potential targets. Subsequent reports will define the influence of these detection boundaries on system performance.

The data obtained in this program were obtained in the field by optically unaided observers, independent of weapon system considerations. As such, this information is applicable to any visual target detection study, subject only to the limitations defined in the text.

OBJECTIVES

This program was designed to determine the range at which optically unaided individual soldiers (typical Redeye operators) could visually detect selected types of target aircraft as a function of target vector, physical background, and mode of alert.

DESCRIPTION OF TEST

TEST SUBJECTS

Personnel to act as subjects for this test were made available by the U.S. Continental Army Command (CONARC) through the U.S. Army Air Defense Board. Subjects were selected to meet the requirements for a typical Redeye operator (see Ref 9).

These requirements include:

1. 20-20 vision or better (corrected).

2. AFQT score of 31 or above.

3. Good judgement.

4. Initiative.

It was later determined, however, that five of the 29 test subjects failed to meet the vision requirement (Appendix F). Data obtained from these subjects are included in overall test results.

Prior to the initiation of test operations, all participants were given a complete briefing in order to develop a high level of interest in the conduct and results of the program. The briefing included:

1. A short description of the Redeye weapon system, and the need for and applicability of valid test results.

2. Operational details of siting and procedures.

3. Effective search procedures. This included vertical scan procedure (to minimize the effect of empty field myopia), horizon referencing, etc. The subjects wer' instructed to utilize any technique which appeared to be individually effective.

Briefings were held as the test proceeded to discuss preliminary results and maintain interest.

Upon completion of the program, all subjects were provided with a comprehensive questionnaire to determine subject reaction to the test. Data obtained from this source have been analyzed separately. (See Ref 11.)

TEST SITE

The test was conducted at the Dona Ana Range, Fort Bliss, Texas, approximately two miles east of the Dona Ana Range Camp. (See Fig 1.)

Fig. 1. Fort Bliss Military Reservation.

RADIO AND INSTRUMENT- ATION SITE

TEST SITE CENTER

RADAR SITE

FORT BLISS MILITARY RESERVATION

CONTOUR INTERVAL 20 FEET
WITH SUPPLEMENTARY CONTOURS AT 5 AND 10 FOOT INTERVALS
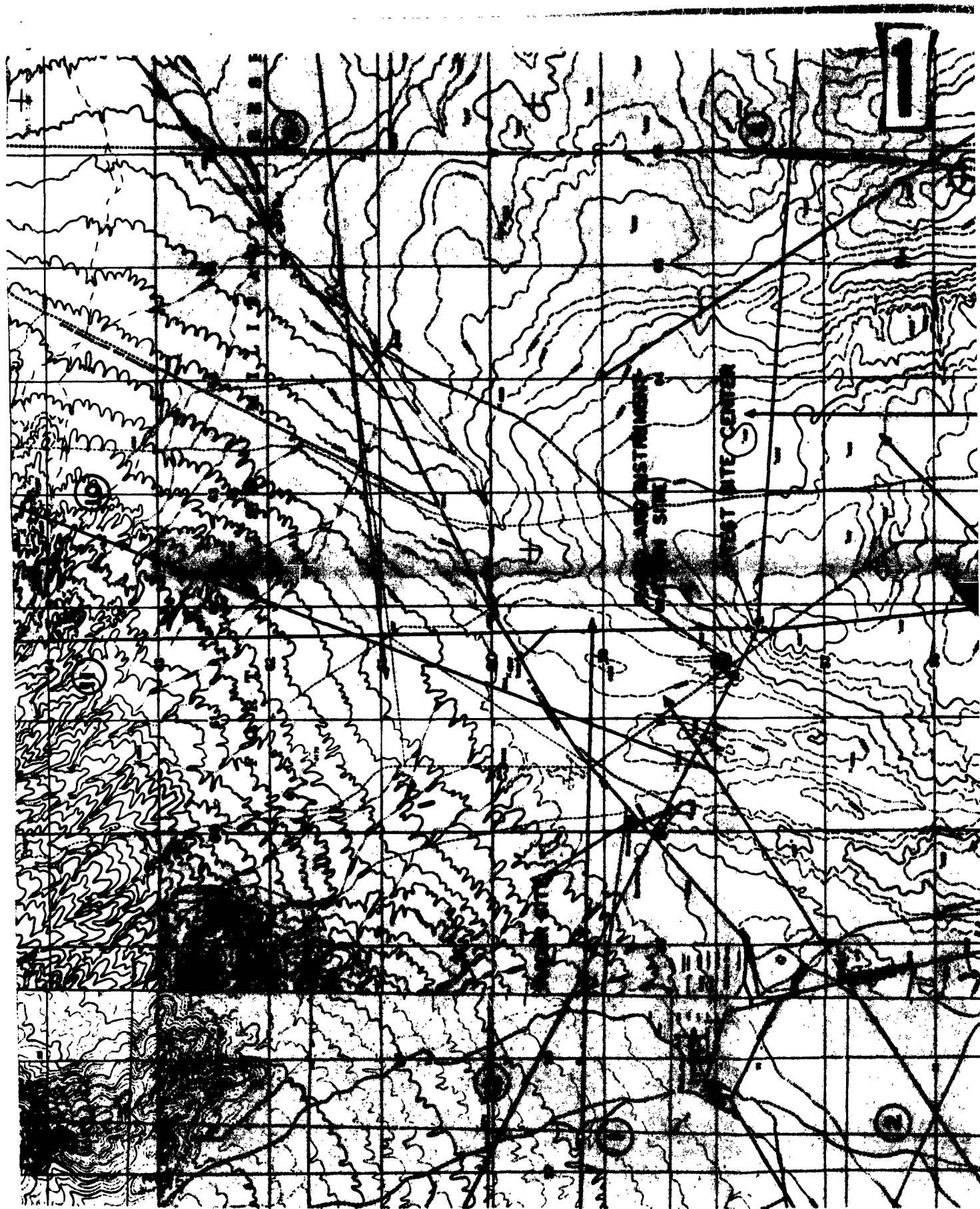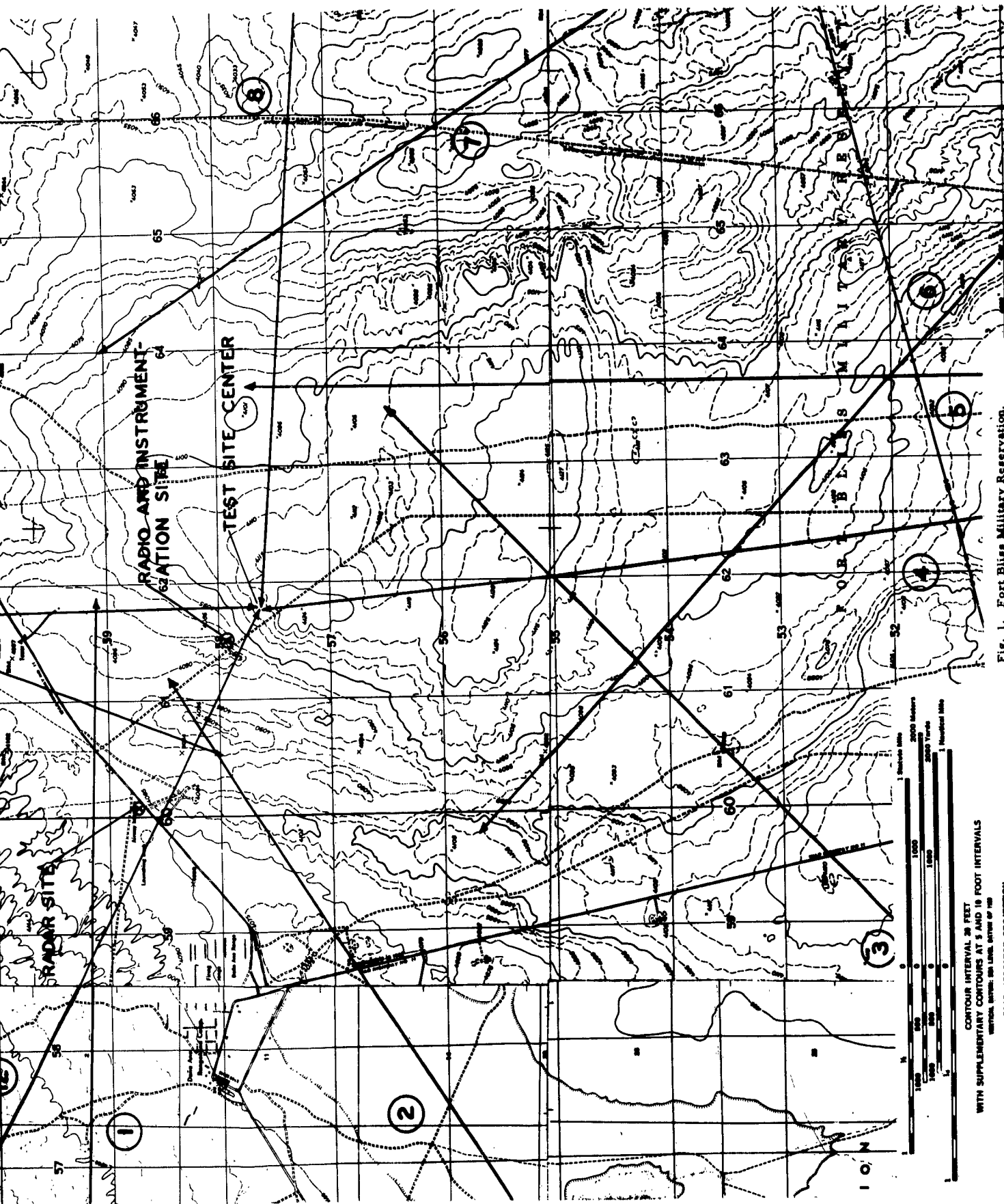
TRANSVERSE MERCATOR PROJECTION

The site was selected to provide:

1. A large unobstructed area for subject positions.

2. Relatively flat approach for target aircraft.

3. Variety of target backgrounds.   (See Appendix D.)

4. Unrestricted air space.

5. Minimum terrain mask for the target tracking radar.

6. Optimum weather conditions.

Twenty-four subjects utilized in each test were positioned as shown in Figure 2.   The subjects (number designation) were located on three concentric circles a minimum of 200 feet apart.   Each quadrant of six subjects was supervised by a test coordinator (letter designation).   The test director was located at the center of this complex and completely screened from subject's view during test operations.

The aircraft control station was located 1/4 mile from the test site. The target track radar was located 1-1/4 mile from the test site.

Every effort was made to insure the independent action of each subject. Unfortunately, complete independence was not achieved as a result of insufficient subject separation. (See Ref 11.) This effect is discussed further in pertinent sections of this report where biased results were obtained.

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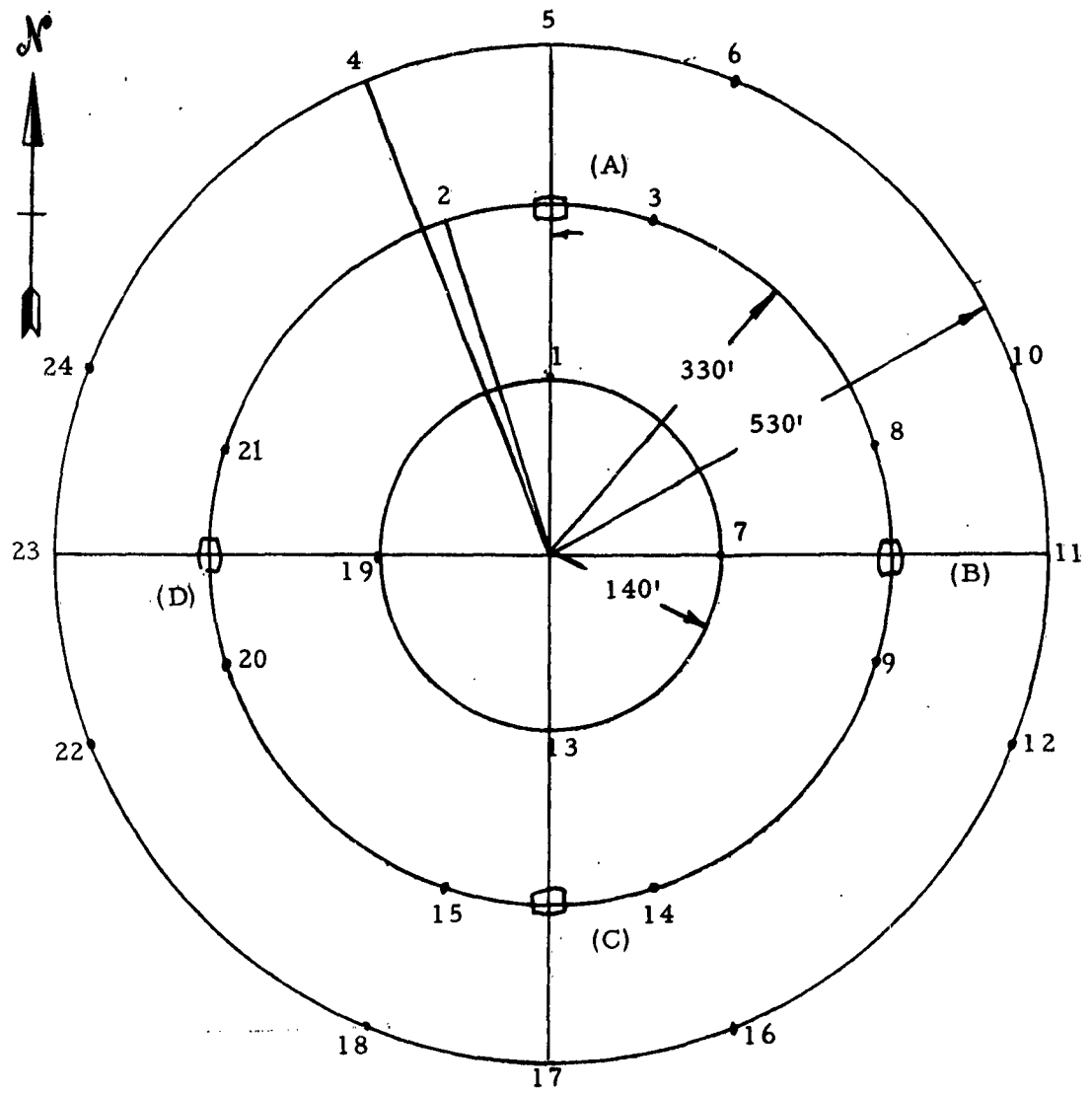
Fig. 2. Test Site Layout

TEST CONDITIONS

All tests were conducted with the following controlled conditions:

1. Target Type, Speed, and Course:

Propeller Aircraft	L-23	100-200 knots
Helicopter	H-23	50- 90 knots
Jet Aircraft	T-33	200-400 knots
	F-100	400-650 knots

    The aircraft flight schedule is provided in Appendix E.

2. Mode of Alert:

Mode 1	30° Search Sector	Approach Known
Mode 2	180° Search Sector	Approach Known
Mode 3	180° Search Sector	Approach Unknown

Target courses were chosen to provide three target aspects at four altitudes*:

Course	Crossing Range
Incoming	0 yd
Incoming-crossing	1,300 to 2,000 yd
Crossing	3,000 to 4,000 yd

Targets approached from several directions (Fig 3). Illustrations in Appendix D, (Fig D-1 thru D-5) show the surrounding area as viewed from the center of the test site. Arrows indicate the initial target position on the horizon at the beginning of the course run.

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* See Table III

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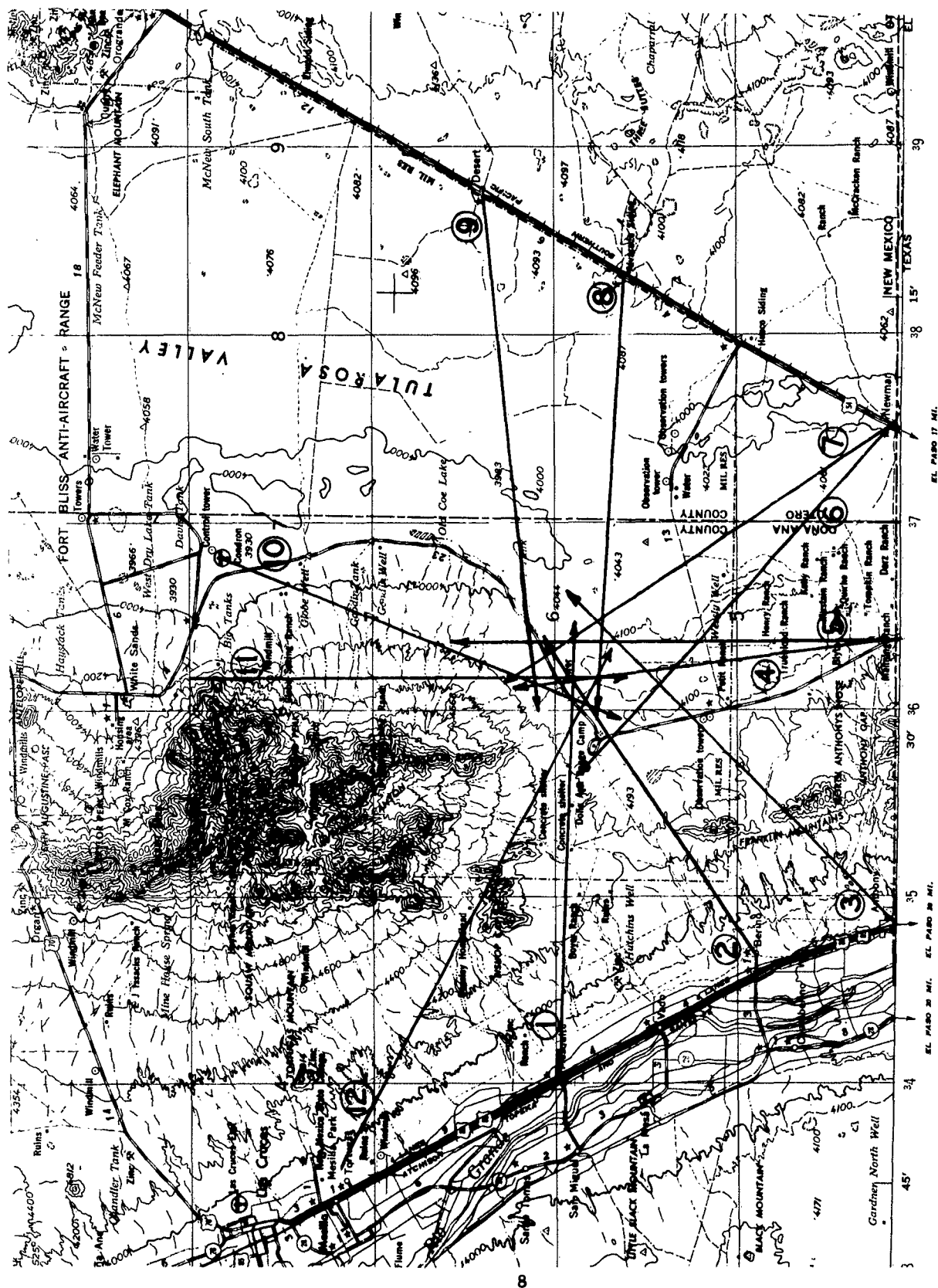
Fig. 3. Target Flight Paths.

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INSTRUMENTATION

An M-33 radar was used to provide aircraft position information. Target position was continuously recorded in X, Y, and H coordinates by 3 Brown Recorders located in the radar van. Test timing was provided by a dual channel portable timing signal generator. Push-button switches operated by each subject were hardwire linked to twenty-four galvanometers on a Data-Rite continuous recorder located in the radio and instrumentation area such that an activation of any switch would cause a deflection of the respective galvanometer. Timing indications and range marks provided the necessary data correlation.

DATA REDUCTION

The following records were utilized in the development of this report

1. Log books containing sun position, test conditions, etc.

2. Oscillograph recordings of target position versus time for each run.

3. Oscillograph recordings of subject's detection indication versus time for each run.

4. Plotting board recordings of target position.

An analysis of errors introduced by the instrumentation and treatment of data indicates a maximum error of ±100 yards in the maximum recorded slant range.

ANALYSIS

The arithmetic mean of the detection range and standard deviation was calculated for all the combinations of tests considered and, by use of the techniques of the analysis of variance, the significant effects upon the Redeye operator's ability to detect the four types of targets were determined. An example of an Analysis of Variance Table is given in Appendix A.

Appendix C contains histograms of the detection range for each type of aircraft. It is evident in these figures, from the skewness to the right, that there is a greater number of detection ranges smaller than the mean range.

Appendix B provides distribution curves of the detection range for each type of aircraft. These accumulative curves give the percent of all observed detection ranges for each aircraft which are greater than a given range. Figure B-5 is the distribution curve of the detection range for all aircraft.

RESULTS

A total of 2,232 range detection observations are analyzed in this study. The following overall results were obtained for all observations:

Mean detection range	5,130 yards
Standard deviation	3,177 yards
Median detection range	4,550 yards
90 percent sample bounds	1,200-11,200 yards
50 percent sample bounds	2,850-6,850 yards

Figure C-2 in Appendix C is the histogram for all these observations; the histogram is highly skewed to the right, indicating an excess in the number of detection ranges smaller than the mean detection range of 5,134 yards.

Figure B-5 in Appendix B gives the distribution curve. From the 95 percent and 5 percent points of the distribution curve, 90 percent of the detection ranges can be found to lie within 1,200 to 11,200 yards.

The following effects upon the operator detection range of aircraft were studied:

1. Type of Aircraft
   a. Single engine propeller (L-23)
   b. Helicopter
   c. F-100 Jet
   d. T-33 Jet

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2.	Target Source	7.	Learning effect of operators
3.	Background of target detection .	8.	Motivation effect of operators
4.	Target altitude	9.	Operator aptitude score
5.	Mode of operator alert	10.	Operator vision
6.	Target speed	11.	Target aspect
		12.	Time-in-alert of operator

The following tables give the number of detection ranges, their mean value, and the standard deviations corresponding to each effect in the aforementioned order. Significant effects appearing in the data are also discussed in the following sections.

The Effect of Target Characteristics Upon the Operator's Ability to Detect. Table I gives the number of target detection ranges, the mean range, standard deviation, and bounds including 90 percent and 50 percent of the ranges for each type of target aircraft.

TABLE I

TARGET COMPARISONS

Type of Target	Nr of Detection Ranges	Mean Detection Range (yd)	Standard Deviation (yd)	Bounds Including 90% and 50% of Detection Range	
				90%	50%
Propeller (L-23)	538	7405	3235	2900 13250	4950 9250
F-100 Jet	613	4432	3255	565 11400	2450 5600
Helicopter	529	5560	2246	1950 9450	4000 6850
T-33 Jet	532	3292	2133	625 7700	2100 3900

There is a highly significant difference in the operator capability of detecting the four types of aircraft as can be seen from the decreasing mean detection ranges in Table I.

The F-100 Jet, because of its larger silhouette (and smoke trail at high speed), is detected at a greater range than the T-33 Jet.

The Propeller aircraft, having the largest silhouette, is detected at longer ranges. The helicopter has the smallest silhouette but also the slowest speed, enabling it to become detected at longer ranges than either of the two jets.

Effect of Target Course Upon the Operator's Ability to Detect. The example in Appendix A, Table A-I, shows the significant effect of target course upon detection range. The apparent interaction of other effects made it impossible to analyze this feature of the test in detail.

Effect of Background Upon Operator's Ability to Detect. Table II below presents the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each of the four types of aircraft against a sky and mountain background.

TABLE II

BACKGROUND EFFECT--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	Sky				Mountain		
	N	$\bar{x}$	S		N	$\bar{x}$	S
Prop (L-23)	385	7637	3324		152	6867	2893
Hel (H-23)	437	5629	2296		90	5351	1996
F-100	540	4874	3222		37	2280	1041
T-33	470	3462	2038		53	3589	2087

The detection range against a pure mountain background is shorter than against a pure sky background. However, it is not significantly different for the T-33 Jet and barely significant for the helicopter. A significantly longer detection range resulted against the sky background for the propeller and F-100 Jet. Sixty-eight zero detection ranges have not been included because of the impossibility of distinguishing them from other "no test" data.

Effect of Altitude Upon Operator's Ability to Detect. Table III presents the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each of the four types of aircraft according to four altitude bands.

TABLE III

ALTITUDE EFFECT--SAMPLE SIZES, MEAN, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	1 150 ft or Less			2 151 to 640 ft			3 550 to 1200 ft			4 750 to 3200 ft		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	113	6661	3047	112	7572	2960				313	7615	3366
Hel (H-23)	110	5696	2947	264	5775	2233				155	5099	2044
F-100	69	2586	1928	128	5237	3524	243	5404	3884	173	3206	1384
T-33	107	3592	1563	136	3507	2602				309	3094	2059

The altitude effect upon the detection range was significant for all aircraft. Table III shows the effect of altitude upon the detection range for the propeller and F-100 Aircrafts at the middle altitude band, but no such increase is evident for the remaining two types of aircraft. It is concluded from the above analysis that detection appears to be optimum at the middle altitude bands; but, because of a lack of a consistent pattern, it is suggested that further investigation of the effects of altitude upon the ability to detect be made.

<u>Effect of Mode of Alert Upon Operator's Ability to Detect</u>.   Table IV
gives the sample size (N), mean (X̄), and standard deviation (S) of the
detection range for each of the four types of aircraft according to the
operator mode of detection.

<u>TABLE IV</u>

<u>MODE OF ALERT--SAMPLE SIZES, MEANS, AND STANDARD
DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE</u>

Target Type	1			2			3		
	N	x̄	S	N	x̄	S	N	x̄	S
Prop (L-23)	205	7192	3699	294	7342	2932	129	7901	2798
Hel (H-23)	175	6188	2178	245	5433	2100	109	4929	2460
F-100	213	5548	1018	310	4345	3186	90	3836	2656
T-33	200	4086	2069	241	2720	1131	111	3883	2811

The modes of detection are:

1.   The operator is alerted and the direction of target approach is known.

2.   The operator is alerted but the direction of target approach is
unknown.

3.   The operator is not alerted and the direction of target approach is
unknown.

The helicopter and F-100 Jet were detected at a significantly longer
range for Mode 1.   The T-33 Jet was detected at a significantly longer
range in operator Modes 1 and 3.   It would be expected that for all target
types, Mode 1 would increase the ease of detection over Mode 2 and Mode 2
over Mode 3.   The fact that no such results are consistently evident would
indicate the need for further study of the problem.

Effect of Aircraft Speed Upon Operator's Ability to Detect. Table V gives the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each of the four types of aircraft according to target speed.

TABLE V

TARGET SPEED (knots)--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE AT VARIOUS TARGET SPEEDS

Target Type	Prop (109-206)			Hel (50-86)			Low Spd Jet (215-410)			High Spd Jet (465-652)		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	538	7405	3235									
Hel (H-23)				529	5559	2268						
F-100							198	4848	2615	415	4233	3567
T-33							552	3292	2133			

From Table V it is clear that detection of the propeller type aircraft is at a considerably greater range than for any other target type; this may be attributed to the large profile as well as its slow speed. The helicopter has the second largest detection range. The reason it is more difficult to detect than the propeller, in spite of its very slow speed, is its very small profile. The F-100 is the only target tested at two speed bands. Detection of the F-100 is at a significantly greater range when flown at the slow speed rather than the fast speed. The poorest detection of all is for the T-33. In fact, it should be observed that the F-100 is easier to detect than the T-33, even when the F-100 flies at a faster speed than the T-33. This situation is attributed to the larger profile and smoke trail for the F-100.

Learning Effect Upon Detection Range of Operator. Table VI gives the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each of the four types of aircraft on each day of test.

TABLE VI

LEARNING EFFECT (DATES OF TEST)--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	17 Oct			18 Oct			19 Oct			20 Oct		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	87	6162	2686	176	7960	3675						
Hel (H-23)	84	5127	2635				69	6127	2087	48	5985	1970
F-100										297	4990	3548
T-33				189	4103	2415	135	2858	1055	167	3698	2118

Target Type	23 Oct			24 Oct			25 Oct*			26 Oct		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	188	6497	2634							87	9582	2522
Hel (H-23)	90	5598	1948	71	5808	1818	63	3748	1563	104	6342	2351
F-100				177	5093	3124	139	3639	1993			
T-33							61	2376	1349			

*Blowing dust occurred on this day.

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Target Type

| Propeller (L-23) | There is a significant difference in detection ranges from day to day with respect to the propeller. The detection ranges alternately become significantly larger and smaller. No test on 25 October (dusty day). |

Propeller
(L-23)

There is a significant difference in detection ranges from day to day with respect to the propeller. The detection ranges alternately become significantly larger and smaller. No test on 25 October (dusty day).

Helicopter
(H-23)

If the dusty day (25 Oct) and the first day of test (17 Oct) are excluded, there are no significant differences in detection ranges during the remaining days, i. e. , operator learning has not significantly changed. The last day of test, however, showed a significantly greater detection range compared with the first day of test.

F-100

Excluding the dusty day (25 Oct), the remaining detection ranges were not significantly different from each other.

T-33

Excluding again the dusty day, there is no significant difference in detection ranges on 18 and 20 October. However, there is a significant difference in detection ranges between 19 and 20 October, indicating better operator performance on 20 October. The difference in altitude of the T-33 on these days may possibly explain the variation in range.

There was a decrease in visibility due to the dust haze in the area--not to blowing dust in the operator's eyes.

Motivation Effect Upon Operator's Ability to Detect. The operators were briefed at the start as to the importance of these tests, and they were given periodic reports of their progress. Table VII gives the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each type of aircraft according to the time of test within the day.

TABLE VII

MOTIVATION EFFECT--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	Early Morning*			Late Morning** - Early Afternoon			Late Afternoon***		
	N	x̄	S	N	x̄	S	N	x̄	S
Prop (L-23)	183	8280	3070	221	5944	2166	134	8620	3938
Hel (H-23)	134	4840	1986	134	6006	2151	64	6271	2496
F-100	157	5352	3691	228	3792	2767	160	5023	3660
T-33:				299	3456	2061	85	2329	1178
From 0800 to 0940	103	2810	1671						
From 1000 to 1050	65	4557	3520						

*0800 to 1045 hours
**1045 to 1400 hours
***1500 to 1700 hours

In general, there is no consistently significant motivation effect. Only the propeller and F-100 showed decreasing and then increasing detection ranges as time progressed. (See Fig C-1.) The propeller aircraft was detected at a significantly longer range during the early morning and late afternoon hours. The helicopter was detected at significantly longer ranges during the late morning and early afternoon hours. The F-100 Jet was detected at a significantly lower range during the late morning-early afternoon period. There is a significant difference in range for the T-33 Jet between

the early morning hours indicated in Table VII. Figure C-1 in Appendix C shows the mean detection range for each aircraft during these time periods. Because of the inconsistency for the various aircraft, further study is necessary before drawing conclusions regarding the effect of the time of day upon the ability to detect.

From 1446 to 1536 hours, there were 197 detection ranges recorded for the helicopter with a mean of 5,516 yards. Also, from 1404 to 1456 hours there were 68 detection ranges for the F-100 Jet with a mean of 3,061 yards.

Operator's Aptitude Score Effect Upon Ability to Detect. Table VIII presents the sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each type of aircraft according to three classifications of the operator's score.

TABLE VIII

APTITUDE SCORE--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	82 - 89			90 - 99			100+		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	187	7158	3080	93	8040	3335	258	7356	3294
Hel (H-23)	177	5480	1938	83	5851	2645	269	5524	2347
F-100	236	4595	3068	62	4579	3565	315	4280	3393
T-33	191	3450	2431	86	3308	2026	275	3178	1937

The propeller aircraft had the only significantly different detection ranges among the three aptitude score intervals. Its detection range was significantly larger when detected by operators with an aptitude score between 90 and 99. On the basis of these data, no explanation can be given of the effect of aptitude score on the detection range for the other aircraft.

Effect of Operator's Vision Upon Ability to Detect. Table IX gives the
sample size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range
for each type of aircraft according to two classifications of operator
vision--those operators with worse than 20/25 vision (of which there were
only four*) and all others.

TABLE IX

OPERATOR VISION INDEX (BOTH EYES)--SAMPLE SIZES, MEANS, AND STANDARD DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	Worse Than 20/25			Other		
	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop (L-23)	86	6260	2551	452	7623	3309
Hel (H-23)	94	4926	1917	435	5697	2317
F-100	109	3445	2300	504	4645	3430
T-33	86	2786	1630	466	3386	2202

It is evident that the observers with a vision index of 20/25 or better
in both eyes detected all types of targets at significantly greater ranges.

Effect of Target Aspect Upon Ability to Detect. Table X gives the sample
size (N), mean ($\bar{x}$), and standard deviation (S) of the detection range for each
type of aircraft as affected by three different target aspects.

1. The propeller aircraft, helicopter, and F-100 Jet had significantly
different detection ranges among the three different target aspects.

2. The propeller type aircraft was detected at a greater distance when
flying the incoming-crossing aspect (Courses 1, 2, 3, 5, and 10).

---

*Operators 2, 6, 9, and 17.

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3. The helicopter was detected at a greater distance when flying the crossing aspect (Courses 6, 7, and 9).

4. However, the F-100 Jet was detected at significantly greater range when flying both the incoming-crossing and the crossing aspects. Figure B-5 in Appendix B shows the distribution curve of the detection ranges for all aspects of all aircraft. Fifty percent of the detection ranges were greater than 4,550 yards, and 5 percent of the detection ranges were greater than 11,000 yards for this target aspect.

TABLE X

TARGET ASPECT--SAMPLE SIZES, MEANS, AND STANDARD

DEVIATIONS FOR EACH AIRCRAFT DETECTION RANGE

Target Type	Incoming			Incoming Crossing			Crossing		
	N	$\bar{x}$	S	N	$\bar{x}$	S	N	$\bar{x}$	S
Prop	196	6912	2722	232	8300	3737	110	6398	2365
Hel	179	5189	2590	216	5530	2203	134	6106	1773
F-100	169	3621	3421	308	4752	3165	136	4714	3246
T-33	267	3363	2467	176	3117	1362	109	3402	2266

Effect of Operator's Time-in-Alert Upon Ability to Detect. During modes of Detection 1 and 2, the operators were in a state of alert less than 15 minutes; in Mode 3 they were in a state of alert from 51 to 91 minutes.

No general conclusions can be reached as to the significance of the length of operator alert time upon the detection range for all aircraft.

CONCLUSIONS

AND

RECOMMENDATIONS

This study provides a realistic statement of the ability of optically unaided observers to detect certain classes of target aircraft. Data are summarized in Table XI.

TABLE XI

STATISTICAL SUMMARY

Type of Target	Number of Detections	Mean Detection Ranges (yds)	Standard Deviations (yds)	Range Limits Including 90% and 50% of Detection Range (yds)	
				90%	50%
Combined Data	2232	5130	3177	1200-11200	2850-6850
Prop (L-23)	538	7400	3235	2900-13250	4950-9250
Hel (H-23)	529	5560	2268	1950- 9450	4000-6850
Jet (F-100)	613	4430	3255	565-11400	2450-5600
Jet (T-33)	552	3290	2133	625- 7700	2100-3900

The data substantiates what would normally be expected of factors influencing detection range, for example:

1. Targets with a large silhouette size are detected at greater ranges than smaller silhouette targets.

2. Targets are more easily seen against a clear sky background.

3. Small search sectors improve detection range.

4. High-speed targets are more difficult to detect than low-speed targets.

It is possible that a bias in the data exists because of observer interaction. This effect could not be evaluated. The bias would tend to improve overall results and, therefore, would not materially affect potential utilization of this information. It is recommended that total isolation of each observer be a requirement for future studies of this type.

This test was conducted in a desert environment, with no terrain masking and excellent visibility. It is expected that similar tests in more temperate climates would not provide as favorable a statement of detection capability. Additional tests in a temperate clime are recommended.

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6. "Redeye Tactical Simulator Field Test" (U), SECRET, Technical Memorandum 812-1-15, Hunter Liggett Military Reservation, California, April-May 1960, General Dynamics/Pomona, Pomona, California, 15 September 1960.

7. "Redeye Tactical Simulator Field Test" (U), SECRET, Technical Memorandum 812-1-9, Camp Pendleton, California, February 1960, General Dynamics/Pomona, Pomona, California, 22 June 1960.

8. "Redeye Development Program" (U), SECRET, Interim Technical Report, Rep Nr CR-590-577-014, Apr-June 1961, General Dynamics/Pomona, Pomona, California, June 1961.

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10. "Numerical Mathematical Analysis, Fourth Edition," UNCLAS-SIFIED, J. B. Scarborough, The Johns Hopkins Press, 1958.

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APPENDIX A

ANALYSIS PROCEDURE

APPENDIX A

ANALYSIS PROCEDURE

A. DEFINITIONS

1. Arithmetic Mean Detection Range (yards)

The arithmetic mean detection range is computed from the formula

$$\frac{1}{N} \sum_1^N x_i, \text{ where } x_i = \text{individual detection range}$$

$$N = \text{number of detection ranges considered in a specific case.}$$

2. Sample Standard Deviation (yards)

The sample standard deviation is computed from the formula

$$S = \sqrt{\frac{\sum_1^N x_i^2 - \frac{(\sum_1^N x_i)^2}{N}}{N-1}}$$

3. Significance Level

The significance level used throughout the statistical tests is at the 5 percent point, i.e., the probability is 0.05 that an error is made in declaring an effect to be real or casual when actually it is random.

4. Histogram

A graph showing the number of detection ranges within specified intervals of the range. (See Appendix C.)

5. Skewness Coefficient

A measure of the departure from symmetry of a distribution, a positive value of which indicates an excess in the number of detection ranges smaller than the mean. For the histogram (Fig C-2) of all of the detection ranges, this coefficient is 1.23.

6. Cumulative Distribution Curve

A curve showing the percent (ordinate) of all detection ranges greater than a particular range (abscissa).

B. SAMPLE METHOD OF ANALYSIS

The Tables A-I and A-II are an example of an analysis of variance study which was computed for determining the effect of target course number upon the detection range of the detection range of the propeller aircraft. Table A-I gives the sample size and mean detection ranges of the propeller aircraft for each of the twelve courses. Table A-II lists the sources of variation, degrees of freedom,the sums of squares and mean squares associated with them, and the computed F-test value of 13.4 which indicates a highly significant effect of course number upon detection range.

TABLE A-I

SAMPLE SIZE AND MEAN DETECTION RANGE OF THE PROPELLER AIRCRAFT FOR EACH OF TWELVE COURSES

Course Nr	1	2	3	4	5	6	7	8	9	10	11	12
Sample Size	47	47	46	45	47	44	42	65	23	45	43	44
Mean Range (yds)	8487	6216	8143	4818	8086	7825	5339	6098	5877	10,664	9012	7023

TABLE A-II

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Sums of Squares $(x 10^9)$	Mean Squares $(x 10^6)$	F-Test
Course	11	1.2287	111.7014	13.4
Error	526	4.3980	8.3613	$= \dfrac{111.7014}{8.3613}$
Total	537	5.6267		

The tabulated F-value for 11 and 526 degrees of freedom is about 1.77 at the 5 percent level of significance.

It is seen from Table A-I that for Course Numbers 1, 3, 5, 6, 10, and 11 the mean range varies from 8,000 to over 10,000 yards, while for Course Numbers 2, 4, 7, 8, 9, and 12 the mean range varies only from 5,000 to 7,000 yards.

The highly significant differences in these means due to the course number is illustrated in Table A-II by the large value of the ratio of the mean square for the effect of the course to the mean square for the error.

APPENDIX B

CUMULATIVE PERCENTAGE OF DETECTIONS

AND NUMBER OF DETECTIONS

VS

DETECTION RANGE

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Fig. B-1. Propeller Aircraft.

CUMULATIVE PERCENTAGE OF DETECTIONS
AND
NUMBER OF DETECTIONS

Fig. B-2. Helicopter.

N = 2231 $\bar{x}$ = 5134   S = 3177 a_3 = 1.23

DETECTION RANGE
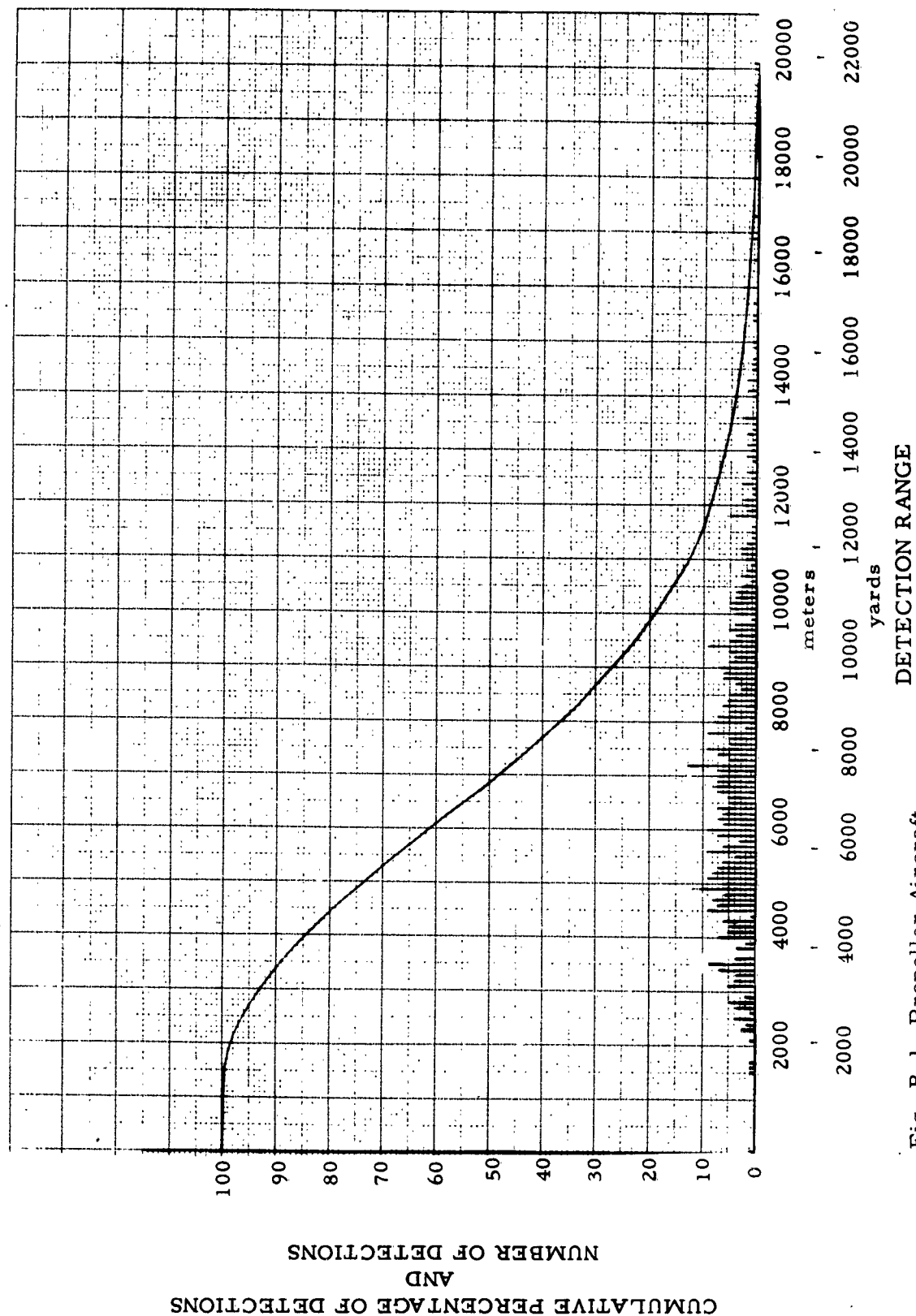
NUMBER OF DETECTIONS
AND
CUMULATIVE PERCENTAGE OF DETECTIONS
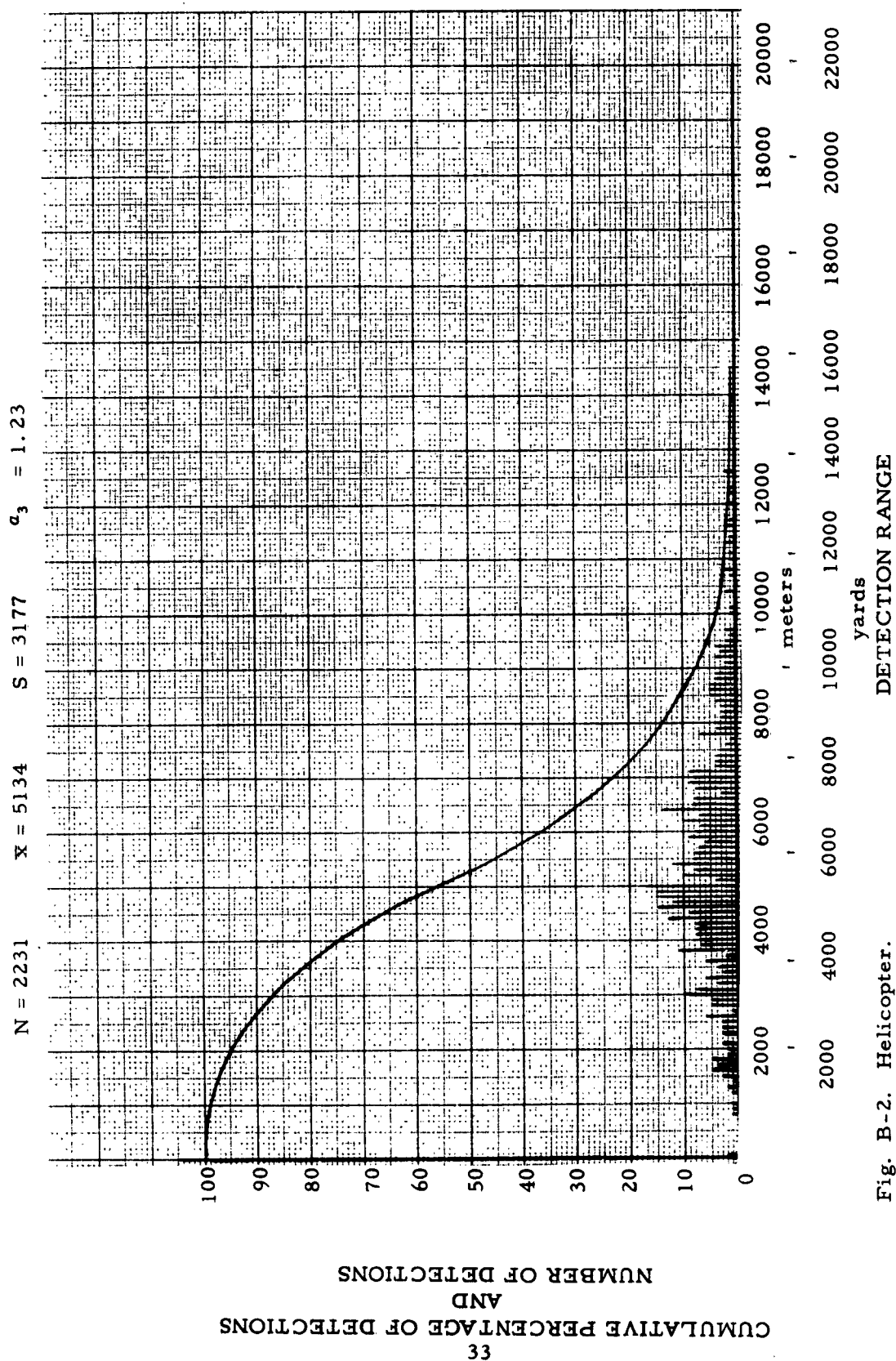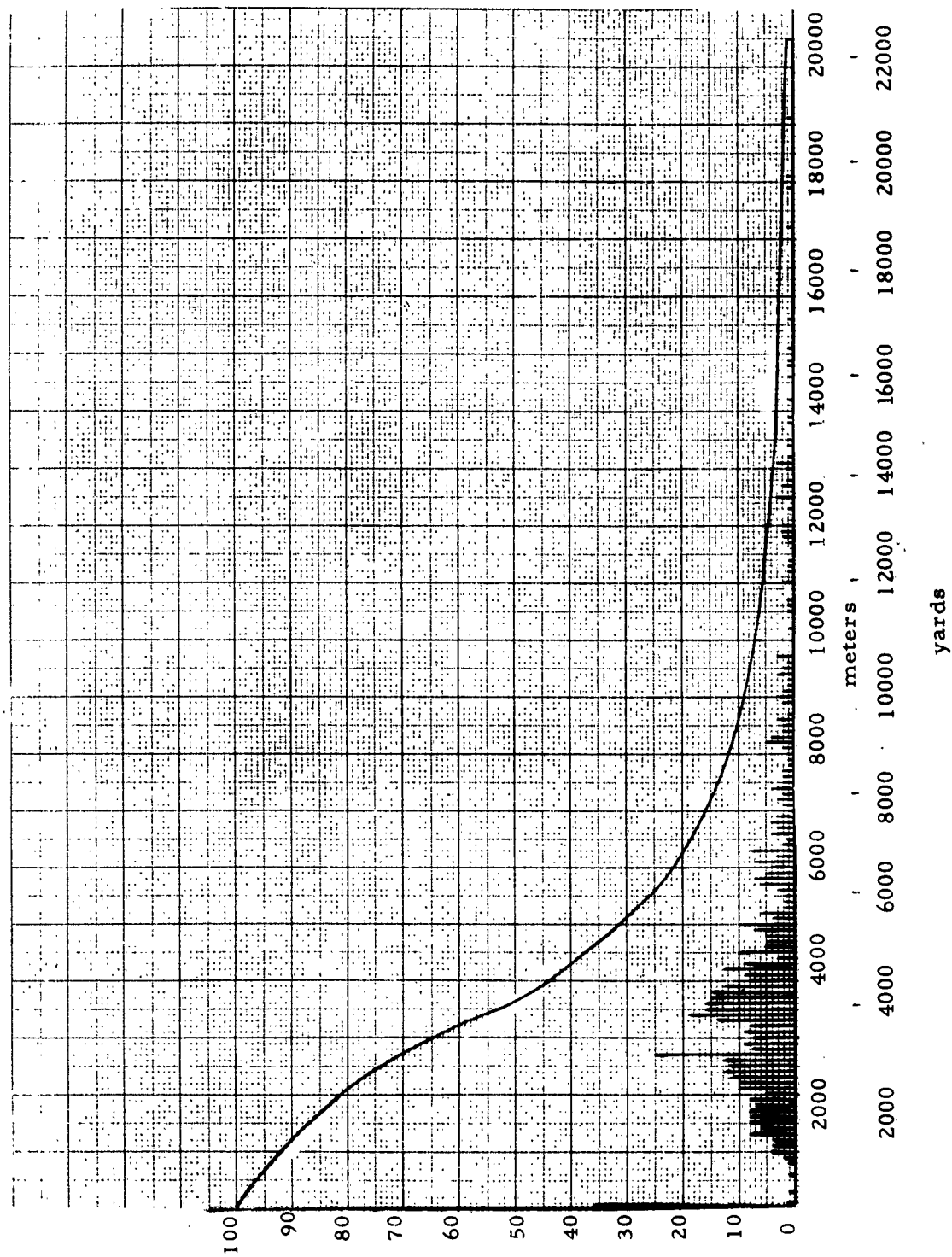
Fig. B-3. F-100 Jet Aircraft.

DETECTION RANGE

CUMULATIVE PERCENTAGE OF DETECTIONS
AND
NUMBER OF DETECTIONS

34

Fig. B-4. T-33 Jet Aircraft

DETECTION RANGE

CUMULATIVE PERCENTAGE OF DETECTIONS
AND
NUMBER OF DETECTIONS

35

Fig. B-5. All Aircraft.

DETECTION RANGE

NUMBER OF DETECTIONS

AND

CUMULATIVE PERCENTAGE OF DETECTIONS

36
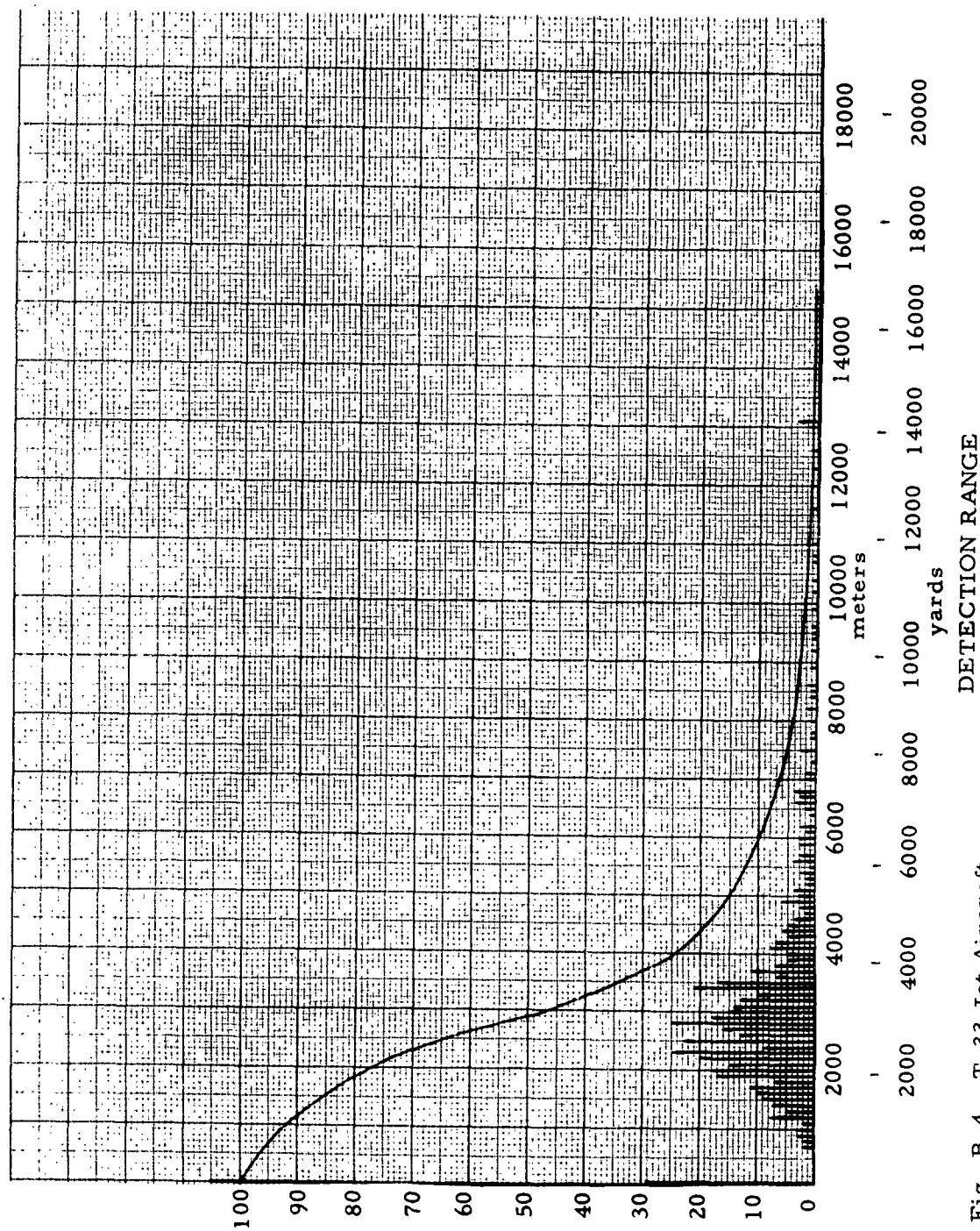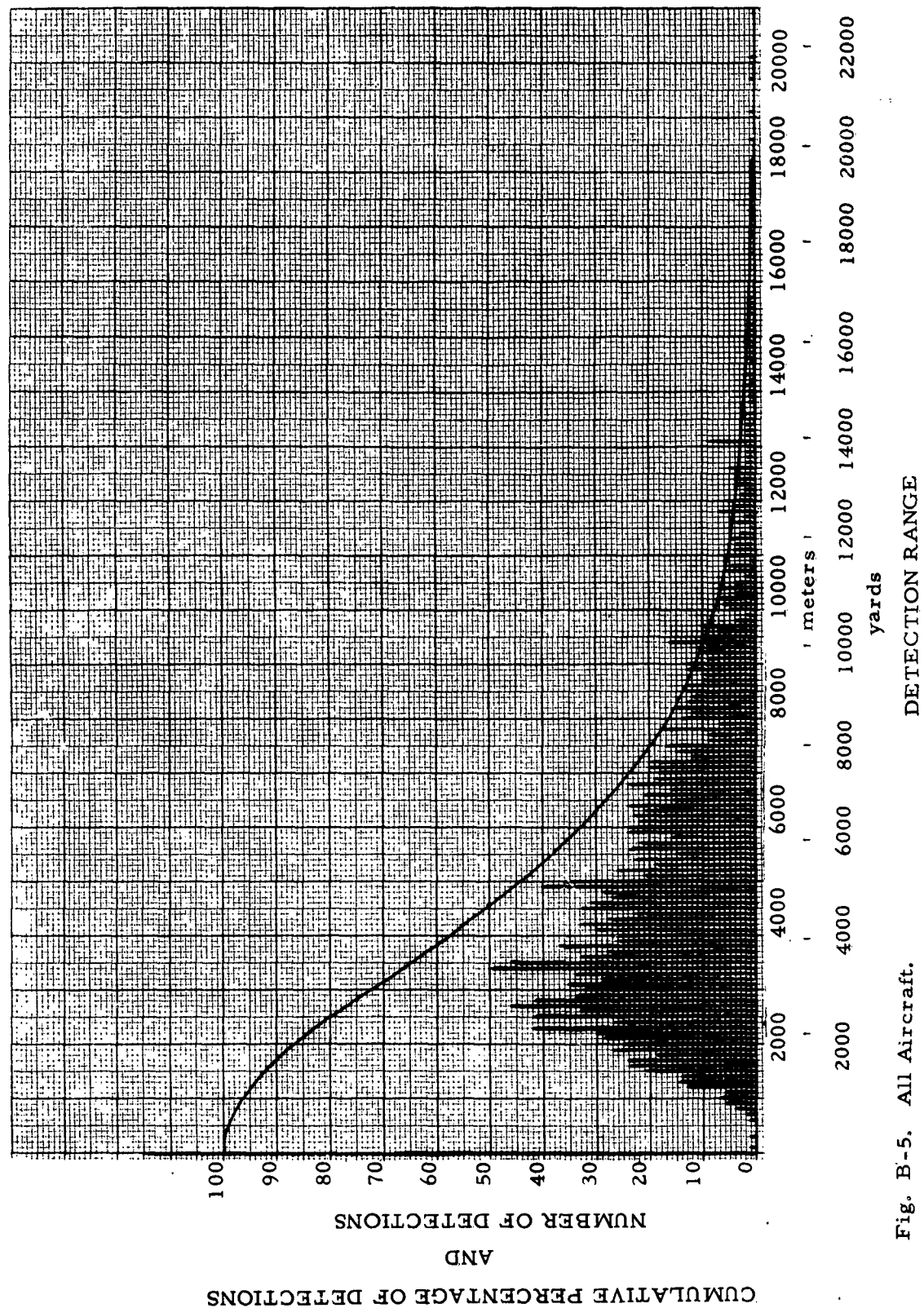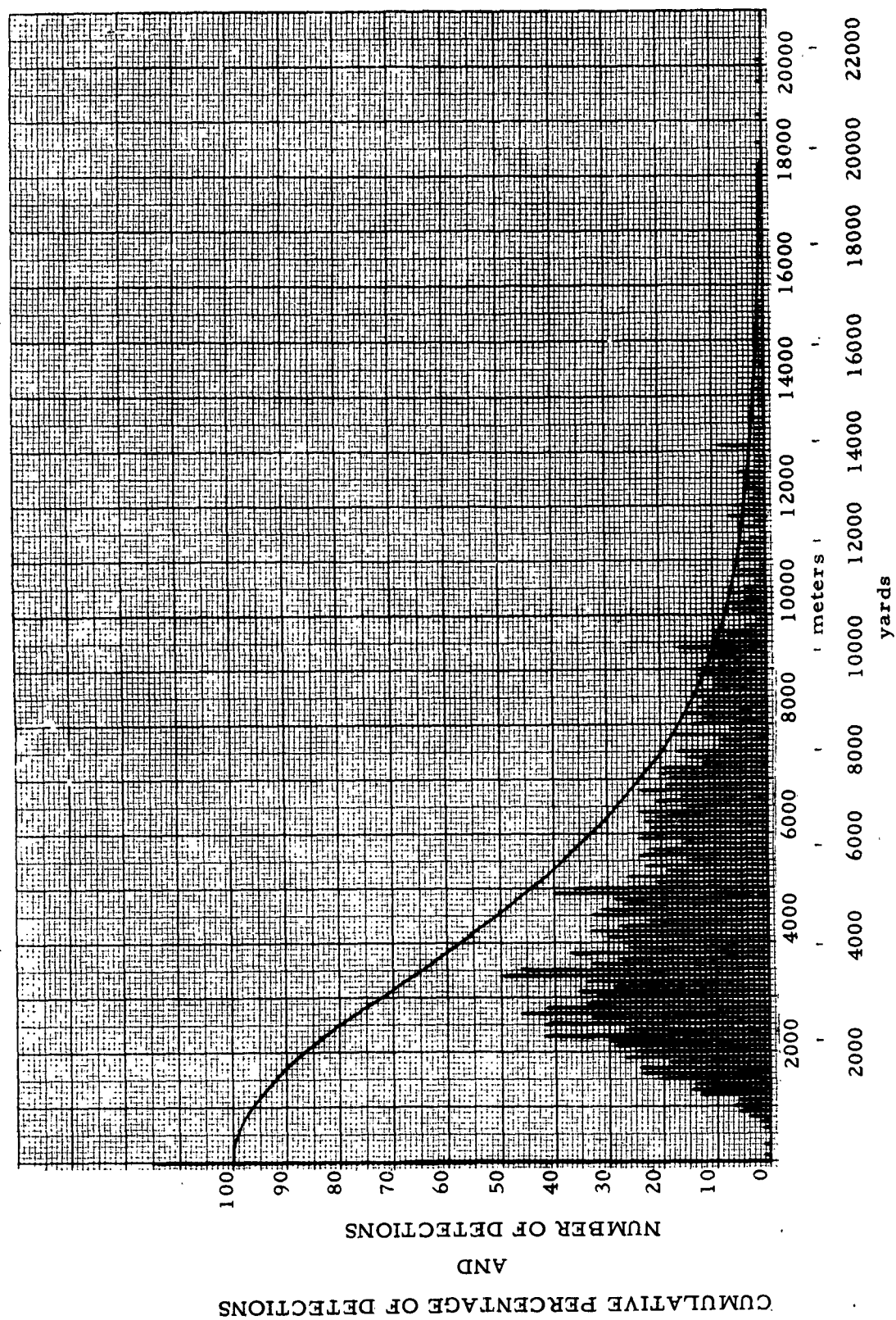
Fig. B-5. All Aircraft.

APPENDIX C

HISTOGRAMS

(NUMBER OF DETECTION RANGES WITHIN SPECIFIED RANGE INTERVALS)

Fig. C-1. Motivation Effect.
(Time of Day)

38
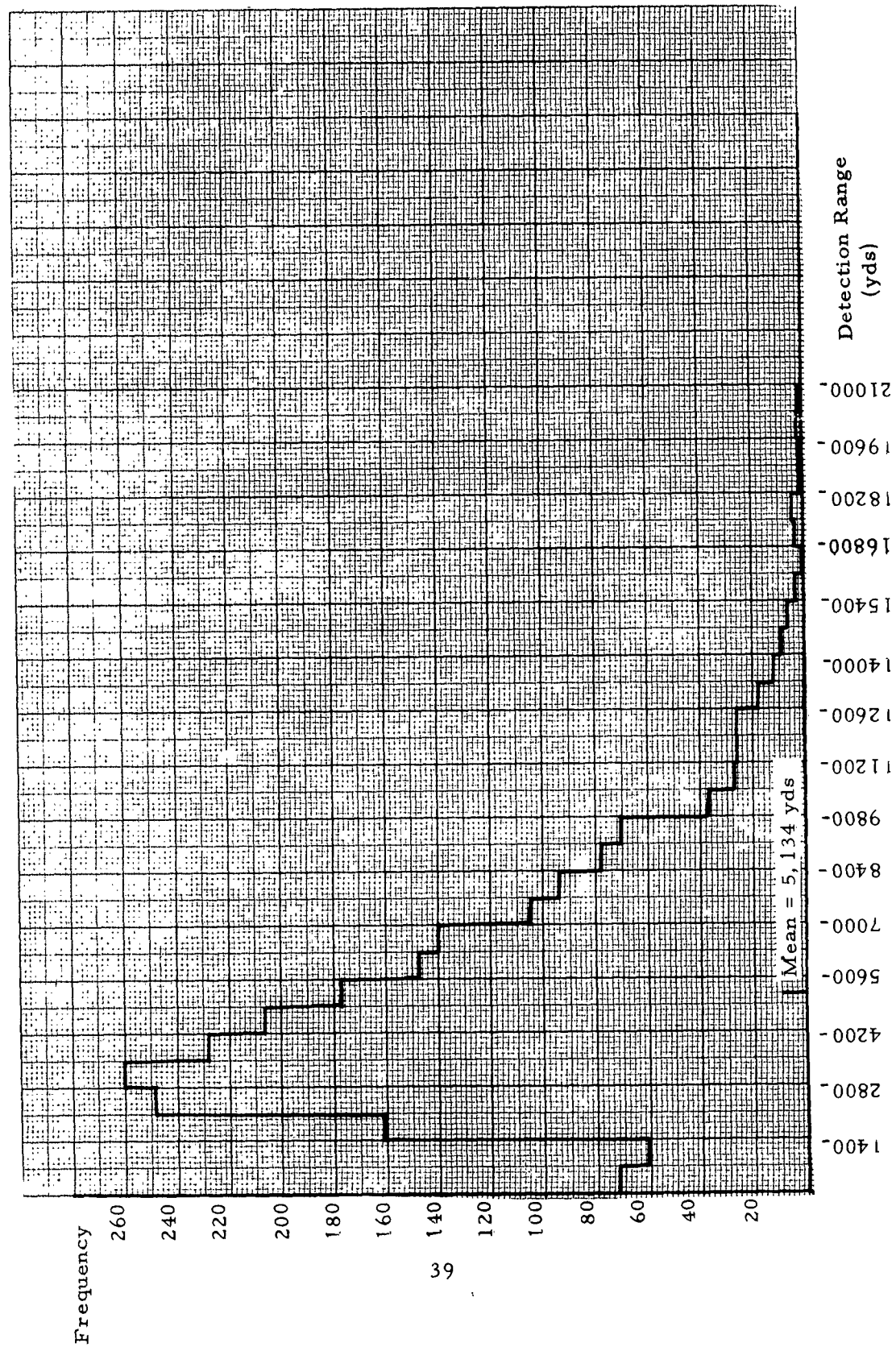
Fig. C-2. Histogram of 2, 232 Detection Ranges for all Aircraft Combined.

39
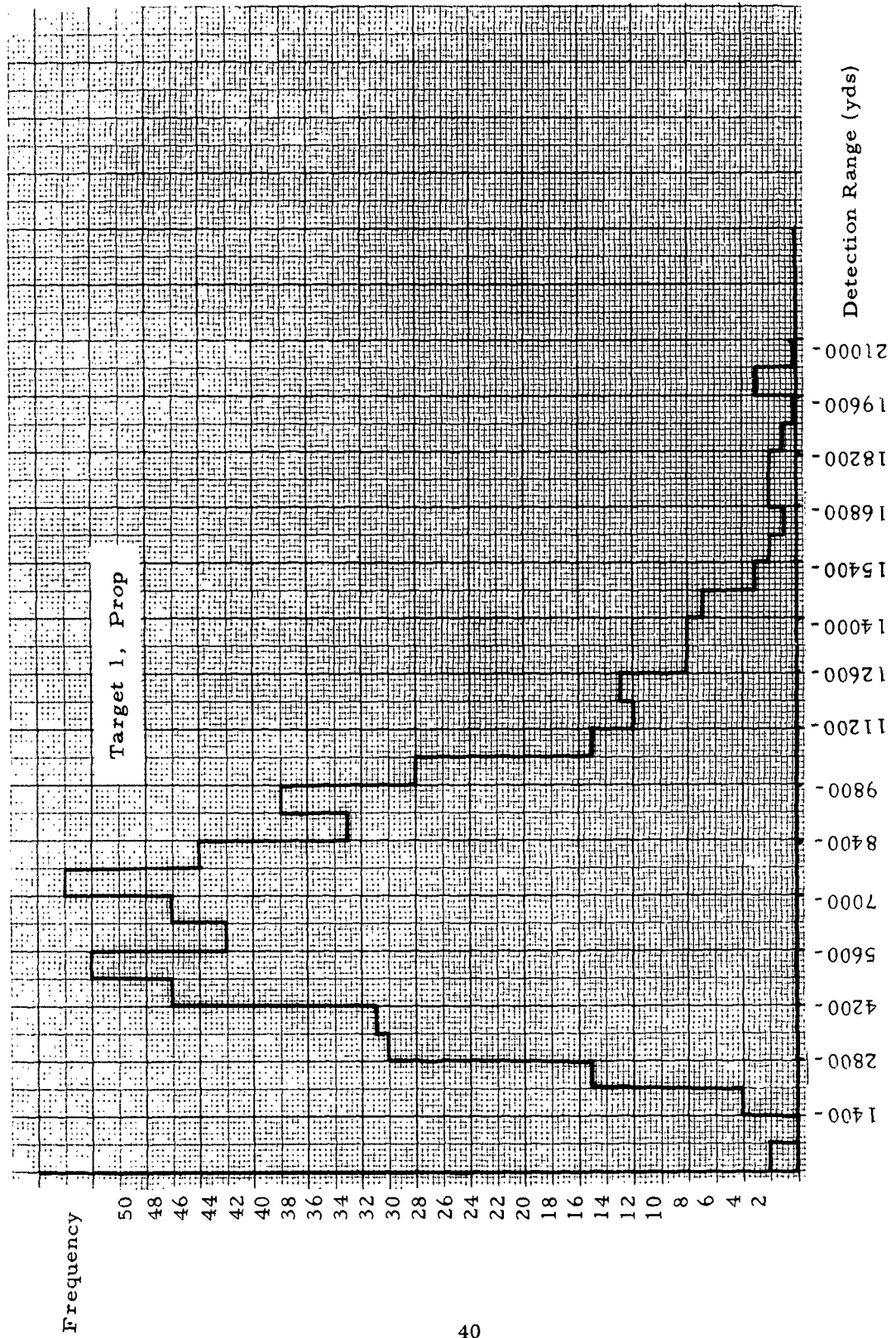
Fig. C-3. Histogram of Detection Ranges for Propeller Aircraft.
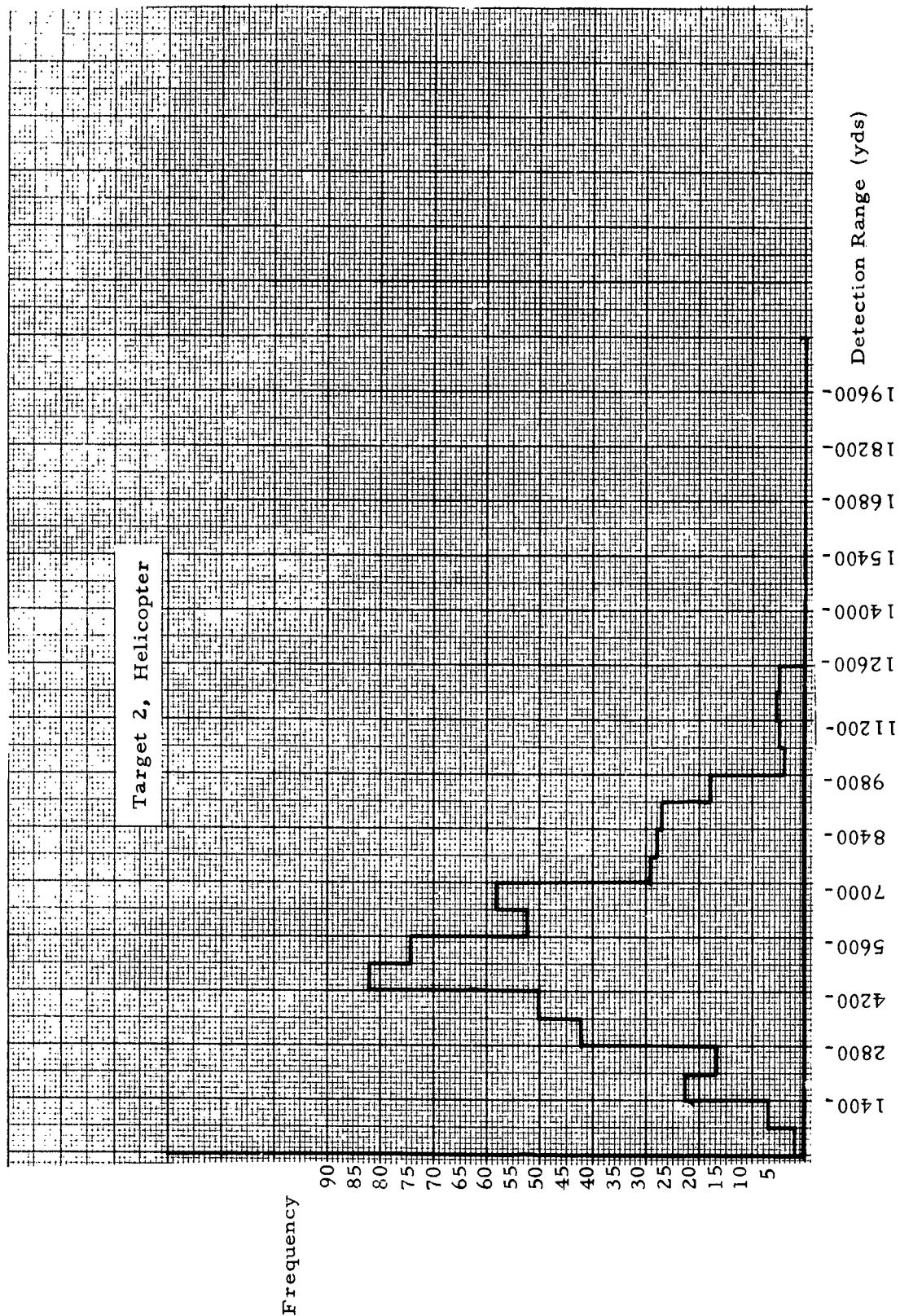
Fig. C-4. Histogram of Detection Ranges for Helicopter Aircraft
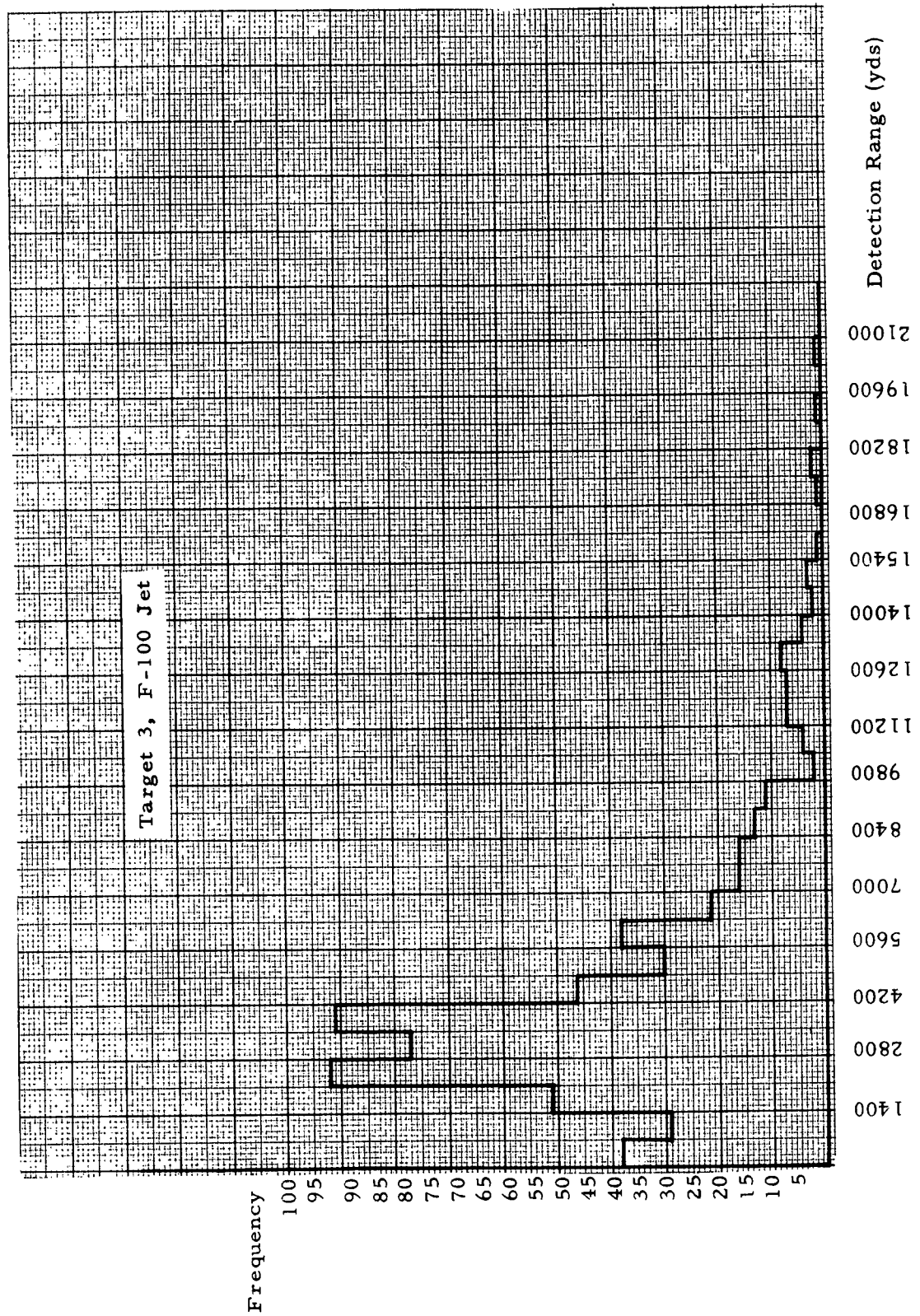
Fig. C-5. Histogram of Detection Ranges for F-100 Jet
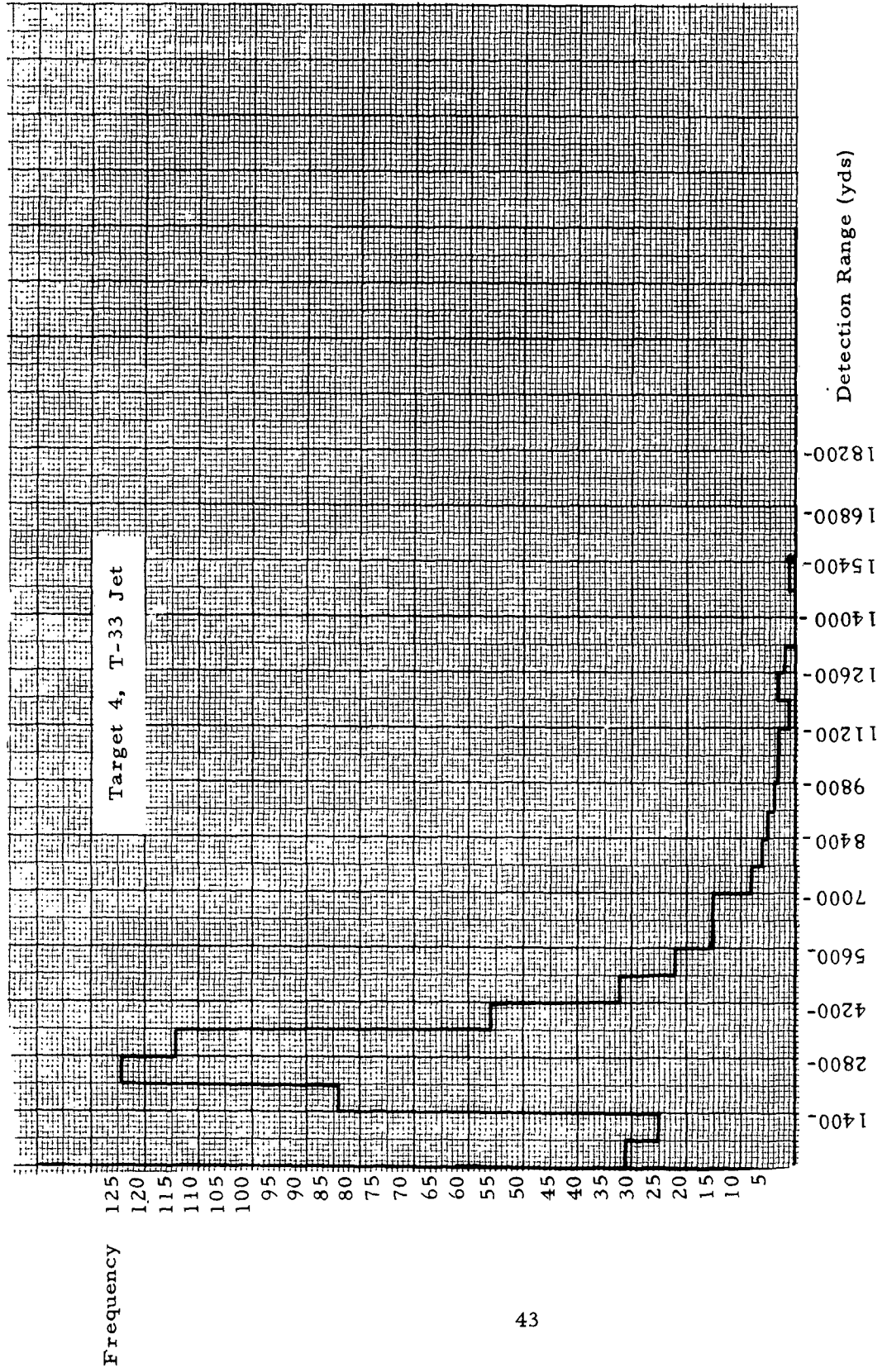
Fig. C-6. Histogram of Detection Ranges for T-33 Jet

APPENDIX D

VIEWS FROM TEST SITE CENTER
WITH COURSE DESIGNATION

Fig. D-1. Test Site--Southwest.
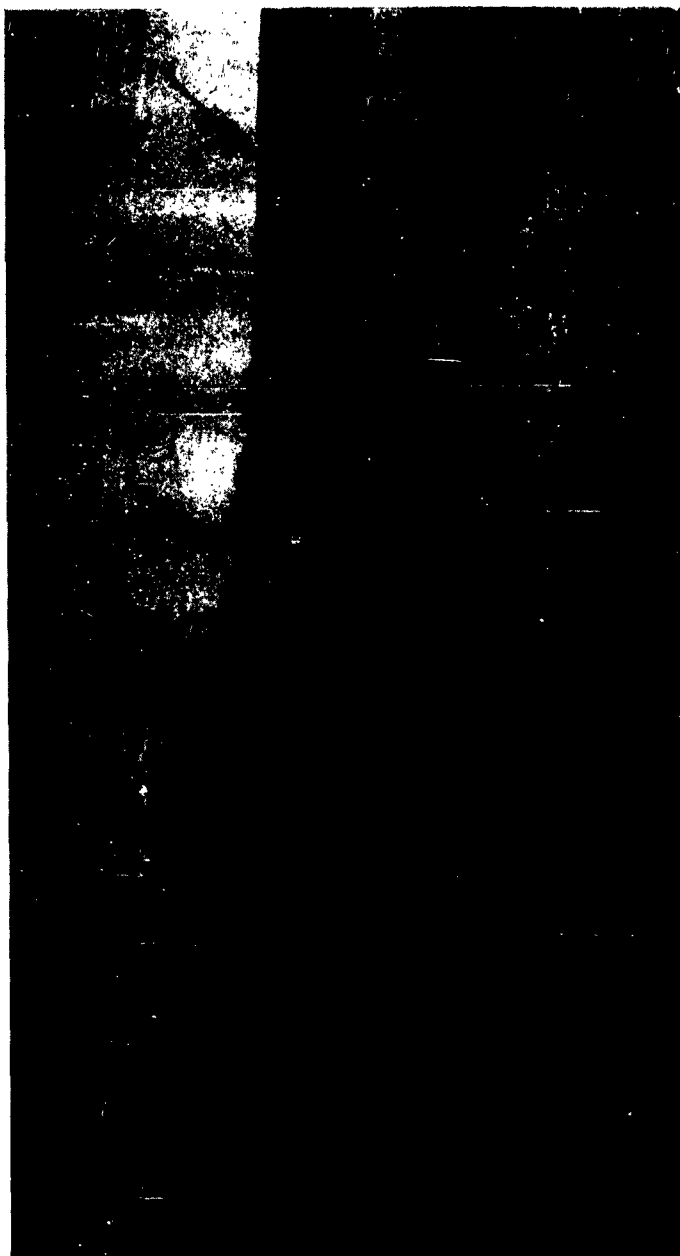
Fig. D-2.　Test Site--North.

47

Fig. D-3. Test Site--South.

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Fig. D-4. Test Site--East.
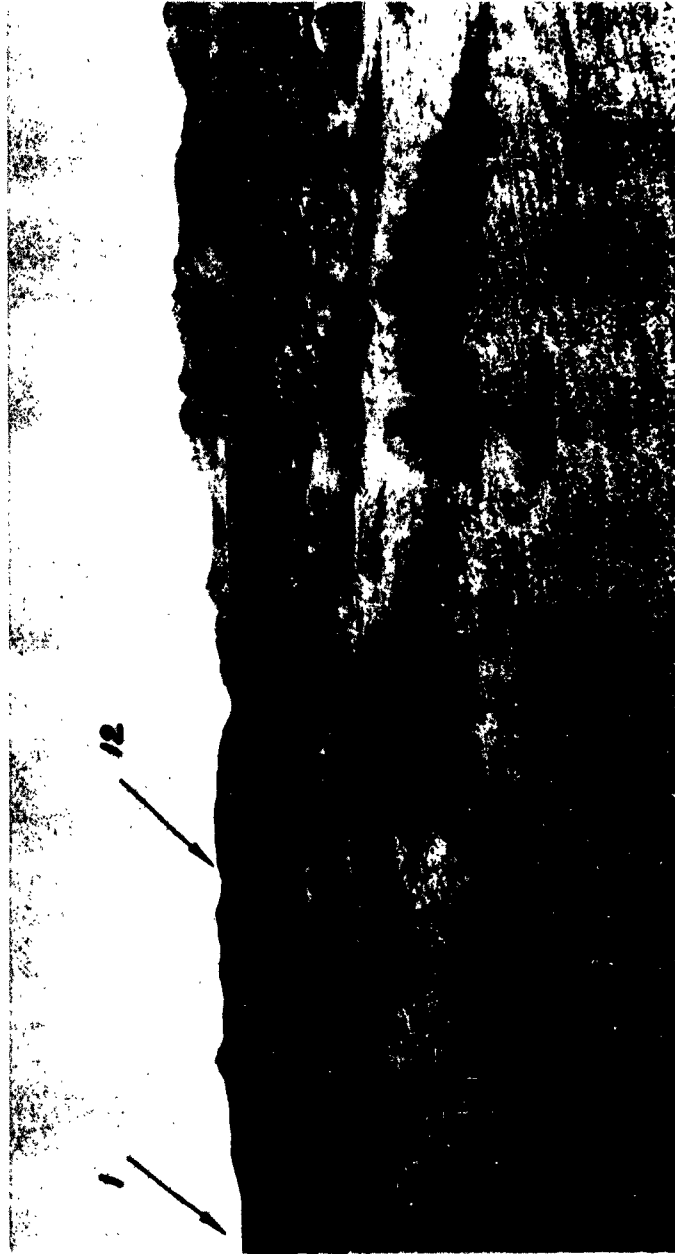
Fig. D-5. Test Site--Northwest.

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APPENDIX E

AIRCRAFT AND AIRCRAFT FLIGHT SCHEDULE

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TABLE E-I

AIRCRAFT FLIGHT SCHEDULE

Date: 17 Oct - Tues

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
1	1045	Propeller	8	150	150	1	9
2	1107	Propeller	11	150	150	2	5
3	1119	Propeller	7	150	1,500	1	4
4	1158	Propeller	4	150	150	1	4
5	1446	Helicopter	7	75	250	2	13
6	1500	Helicopter	11	75	250	2	8
7	1613	Helicopter	12	75	1,000	3	47
8	1630	Helicopter	5	75	250	2	8

Date: 18 Oct - Wed

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
9	0805	Jet	2	300	500	2	10
10	0814	Jet	11	450	500	2	7
11	0817	Jet	5	450	2,500	1	4
12	0934	Jet	11	300	500	2	10

Table E-I (cont)

Date: 18 Oct - Wed

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
13	0939	Jet	7	300	2,500	2	4
14	1009	Jet	12	450	2,500	3	30
15	1014	Jet	4	300	2,500	1	3
16	1141	Jet	1	450	500	3	42
17	1150	Jet	4 (tactical)	450	30	1	3
18	1306	Propeller	4	150	1,500	2	5
19	1347	Propeller	12	150	150	3	33
20	1503	Propeller	11	150	1,500	3	43
21	1512	Propeller	5	150	150	2	4
22	1522	Propeller	10	150	150	1	6
23	1531	Propeller	2	150	1,500	2	3
24	1549	Propeller	12	150	1,500	2	6
25	1558	Propeller	7	150	150	2	5

Table E-I (cont)

Date: 19 Oct - Thur

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
26	1054	Jet	2	300	2,500	2	2
27	1100	Jet	8	300	2,500	2	2
28	1106	Jet	12	300	500	1	2
29	1328	Jet	3	300	500	3	64
30	1338	Jet	10	450	2,500	1	7
31	1347	Jet	9	450	2,500	2	4
32	1507	Helicopter	4	75	2,500	2	7
33	1536	Helicopter	12	75	250	1	12
34	1658	Helicopter	7	75	1,000	2	8

Date: 20 Oct - Fri

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
35	0825	Jet (F-100)	6	450	2,500	2	3
36	0836	Jet (F-100)	1	300	500	1	4
37	0841	Jet (F-100)	6	450	500	2	3
38	0900	Jet (F-100)	10	450	500	3	11

Table E-I (cont)

Date: 20 Oct – Fri

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
39	0904	Jet (F-100)	3	300	2,500	1	2
40	0909	Jet (F-100)	8	300	250	2	2
41	0915	Jet (F-100)	5	300	500	2	1
42	1114	Helicopter	1	75	1,000	2	10
43	1131	Helicopter	4	75	250	2	7
44	1315	Jet (T-33)	2	300	2,500	2	2
45	1405	Jet (T-33)	5	300	2,500	3	19
46	1412	Jet (T-33)	11	300	2,500	1	3
47	1419	Jet (T-33)	7	300	2,500	2	3
48	1425	Jet (T-33)	12	300	500	1	2
49	1431	Jet (T-33)	9	300	500	1	3
50	1540	Jet (F-100)	4	450	500	3	40
51	1545	Jet (F-100)	1	450	2,500	2	2
52	1548	Jet (F-100)	6	450	500	2	2

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Table E-1 (cont)

Date: 20 Oct - Fri

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
53	1555	Jet (F-100)	12 (tactical)	350	100	2	3
54	1559	Jet (F-100)	7	500	750	1	1
55	1602	Jet (F-100)	11 (tactical)	600	50	2	1
56	1607	Jet (F-100)	3 (tactical)	550	20	1	1

Date: 23 Oct - Mon

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
57	0907	Propeller	1	150	150	3	52
58	0917	Propeller	6	150	1,500	1	4
59	0933	Propeller	10	150	1,500	2	4
60	0950	Propeller	3	150	150	1	6
61	1043	Propeller	8	150	1,500	3	43
62	1053	Propeller	2	150	150	2	4
63	1118	Propeller	5	150	1,500	1	3
64	1130	Propeller	9a	150	150	2	5
65	1307	Helicopter	6	75	1,000	1	11

Table E-1 (cont)

Date: 23 Oct - Mon

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert(min)
66	1446	Helicopter	10	75	250	3	91
67	1508	Helicopter	3	75	1,000	2	6
68	1528	Helicopter	8	75	50	1	7

Date: 24 Oct - Tue

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert(min)
69	1015	Helicopter	6	75	250	3	67
70	1030	Helicopter	1	75	250	1	5
71	1046	Helicopter	10	75	1,000	2	7
72	1325	Jet (F-100)	10	300	2,500	3	41
73	1332	Jet (F-100)	3	450	2,500	2	3
74	1341	Jet (F-100)	8	450	500	1	3
75	1345	Jet (F-100)	2 (tactical)	550	250	2	1
76	1349	Jet (F-100)	11	650	100	2	2
77	1450	Jet (F-100)	2 (tactical)	450	500	3	51
78	1456	Jet (F-100)	9	300	2,500	1	3

Table E-1 (cont)

Date: 24 Oct - Tue

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
79	1501	Jet (F-100)	5	450	500	2	2

Date: 25 Oct - Wed

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
80	0855	Helicopter (H-23)	8	75	1,000	3	27
81	1021	Helicopter (H-23)	9	75	250	2	4
82	1040	Helicopter (H-23)	2	75	250	1	9
83	1115	Jet (F-100)	7	300	500	1	5
84	1317	Jet (F-100)	12	450	2,500	3	48
85	1327	Jet (F-100)	4	450	500	2	2
86	1331	Jet (F-100)	1	450	2,500	1	2
87	1355	Jet (F-100)	10	300	500	2	3
88	1359	Jet (F-100)	3	450	500	1	1
89	1404	Jet (F-100)	8	450	500	2	1
90	1523	Jet (T-33)	8	300	2,500	3	40
91	1532	Jet (F-100)	6	300	2,500	2	1

Table E-I (cont)

Date: 25 Oct - Wed

Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
92	1538	Jet (T-33)	12	300	300	1	4

Date: 26 Oct - Thur

| Run	Actual Time	Type of Aircraft	Course	Speed (knots)	Altitude (feet)	Mode	Time in Alert (min)
93	0840	Propeller	3	150	1,500	3	30
94	0922	Propeller	6	150	150	3	25
95	0932	Propeller	1	150	1,500	2	5
96	0942	Propeller	8	150	1,500	1	5
97	1319	Helicopter	9	75	1,000	3	44
98	1337	Helicopter	5	75	1,000	1	7
99	1355	Helicopter	3	75	250	2	7
100	1519	Helicopter	11	75	1,000	1	11
101	1536	Helicopter	2	75	1,000	1	8

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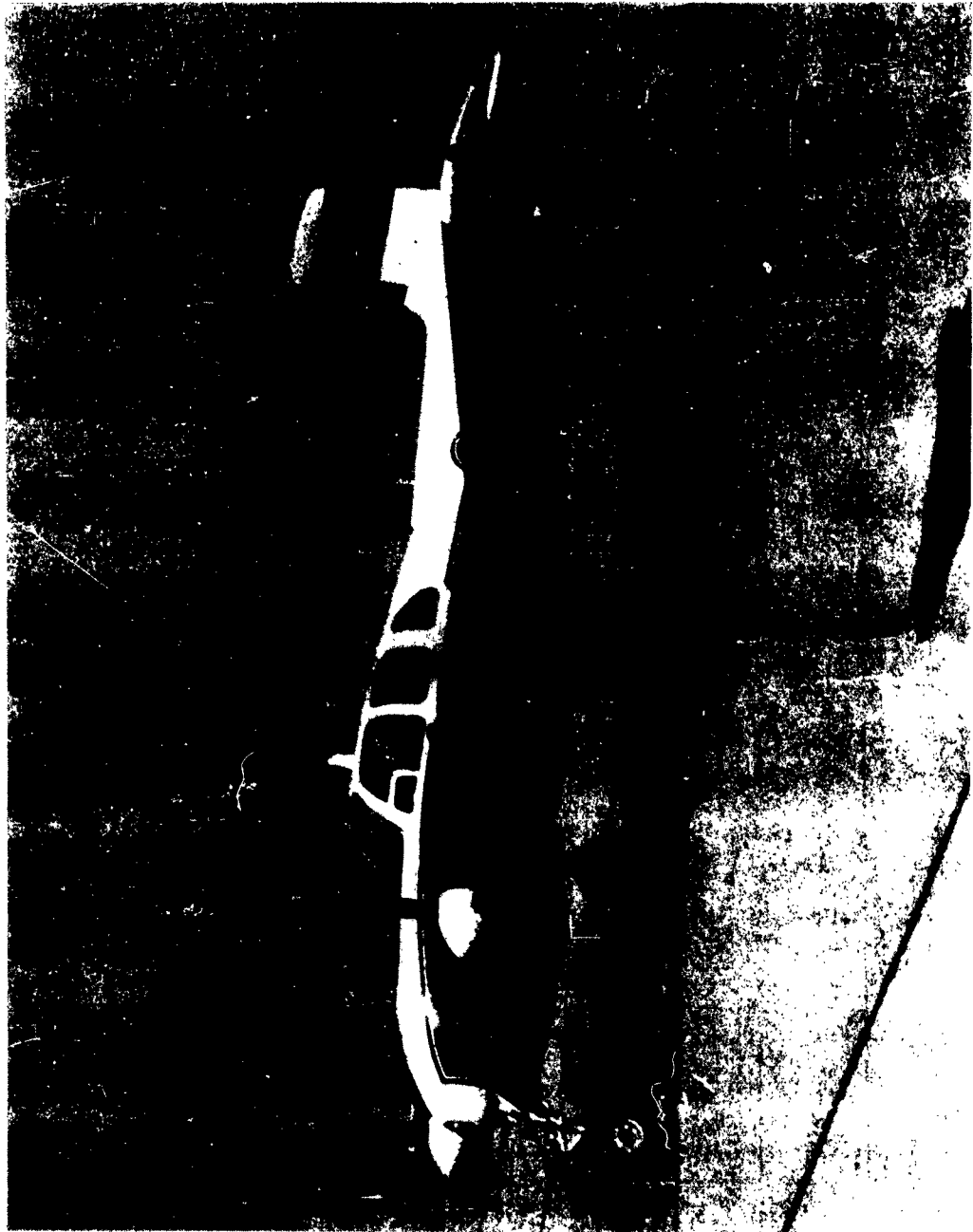
Fig. E-1. L-23 Twin Engine Propeller Aircraft.
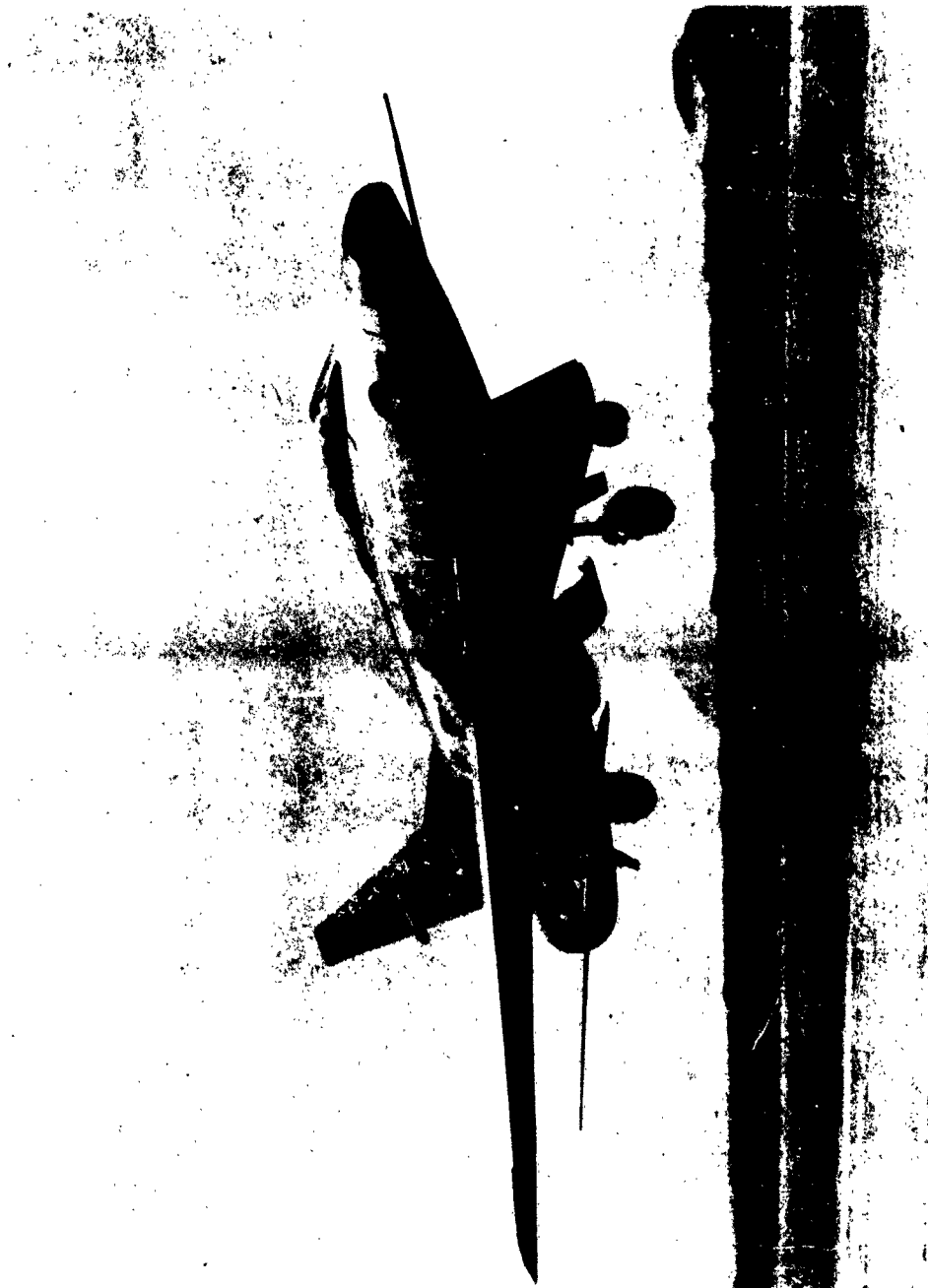
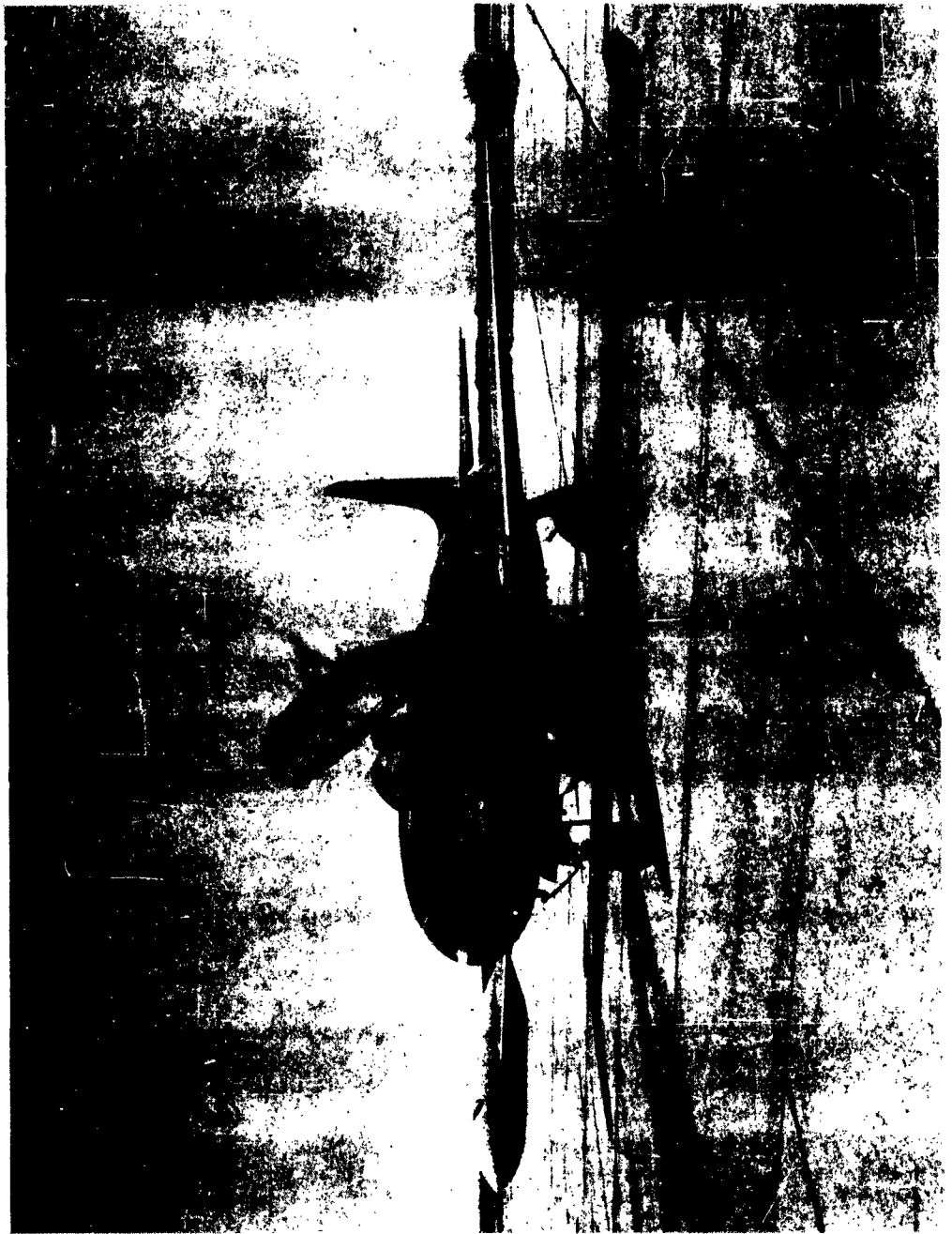Fig. E-2. H-23 Helicopter.

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Fig. E-3. F-100 Jet Aircraft

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Fig. E-4. T-33 Jet Aircraft

TABLE F-I

OPERATOR CHARACTERISTICS

Operator ID Letter	Eye Score R	Eye Score L	Aptitude (Av. Test Score)	Color Test Score	Hearing (Audiometer Score)											
					500 Cycles		1000 Cycles		2000 Cycles		3000 Cycles		4000 Cycles		6000 Cycles	
					R	L	R	L	R	L	R	L	R	L	R	L
A	20/15	20/15	88	18	0	0	0	0	0	0	0	0	10	15	0	15
B	20/15	20/15	87	17	-10	40	-10	5	-10	-10	30	-10	-10	-10	40	-10
C	20/15	20/15	85	18	5	5	0	0	0	0	0		0	0		
D	20/15	20/15	87	18	0	0	0	0	0	0			10	5		
E	20/15	20/15	96	18	10	5	10	5	0	0	0	0	5	5	25	55
F	20/15	20/15	104	18	0	0	0	0	0	0	0	0	0	50	10	40
G	20/15	20/20	88	18	5	0	5	5	0	0			10	50		
H	20/15	20/15	88	16	-5	0	-5	-10	0	-5	-5	-5	-5	0	10	25
I	20/15	20/15	99	16	0	45	0	5	0	0	0	0	0	5	0	5
J	20/15	20/15	96	17	0	0	0	0	0	0	0	0	0	5	0	0
K	20/15	20/15	109	18	5	5	-5	5	5	5	0	0	5	15	15	45
L	20/15	20/15	89	17	-10	-5	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
M	20/15	20/15	114	17	5	0	0	0	0	0	25	20	40	35	25	55
N	20/15	20/20	101	18	-5	-5	-5	-5	-10	-5	-10	-5	-10	-5	15	20
O	20/20	20/20	84	16	-5	-5	0	5	-10	15	-10	10	5	5	15	45
P	20/20	20/20	98	18	-5	10	-5	0	-5	-5	-5	5	5	15	15	15

Table F-I (cont)

Operator ID Letter	Eye Score (Letter) R	Eye Score (Letter) L	Aptitude Score	Av. Test Score Color (Score)	Hearing (Audiometer Score) 500 Cycles R	500 Cycles L	1000 Cycles R	1000 Cycles L	2000 Cycles R	2000 Cycles L	3000 Cycles R	3000 Cycles L	4000 Cycles R	4000 Cycles L	6000 Cycles R	6000 Cycles L
Q	20/20	20/25	88	18	-5	0	-5	-5	-5	5	0	5	5	5	10	20
R	20/20	20/20	89	16	0	0	-5	-5	-10	-5	-10	-5	0	5	-10	-5
S	20/25	20/20	102	18	-5	-5	-5	-5	25	-5	50	20	50	40	55	40
T	20/20	20/20	110	18	10	30	0	5	0	15	5	10	15	20	45	50
U	20/20	20/20	102	18	0	0	0	0	0	0	10		10	5		
V	20/20	20/20	122	18	-5	5	-5	-5	-10	-5	10	30	15	50	40	30
W	20/20	20/20	121	18	10	0	0	0	0	0	0	0	15	15	15	20
X	20/20	20/20	121	18	5	0	0	0	0	0	0	0	0	15	5	30
Y	20/20	20/20	98	14	0	0	0	0	-10	0	0	0	0	5	15	30
Z	20/40	20/40	82	18	-5	0	-5	-10	-10	-10	-10	-5	5	-5	10	15
AA	20/20	20/100	121	18	0	0	0	0	0	0	0	0	0	0	0	5
BB	20/40	20/40	115	18	0	0	0	0	0	0	0	0		0	10	5
CC	20/L	20/L	125	18	5	5	0	0	0	0	0	0	10	25	50	50

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Systems Test Division, The Army Missile Test
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Range, New Mexico.
REDEYE TARGET DETECTION STUDY, by
Lt W. J. Zimmer and C. F. McGinnis, Technical
Memorandum 1072, March 1963, 66 pp incl illus.

UNCLASSIFIED Report

The Redeye target detection study was con-
ducted by White Sands Missile Range at Dona Ana
Range, Ft Bliss, Texas, during the period 17
through 27 October 1961. Tests were conducted
to determine the range at which "average"
soldiers, without optical aids, could visually
detect target aircraft.

Analysis of data provided detection range
information as a function of target type, altitude,
direction, speed, and degree of prior information
provided the subjects.

ACCESSION NR

1. Redeye Weapon System
2. Visual Detection of Target
   Aircraft
3. Detection Boundaries
   (without Optical Aids)
4. OMS Code 5210.12.128
   DA Project 516-04-012

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